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APPLYING TECHNOLOGY FOR THE PROTECTION OF THE CITIZEN AND SOCIETY

INSTITUTE FOR SYSTEMS, INFORMATICS AND SAFETY

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The start of the Fifth Framework Programme has seen a strong growth for ISIS in those areas of research where demand for sound science to underpin EU policy is clear and growing. ISIS' strongest growth is in research related to security and reliability in the information society, and the fight against fraud. This reflects the rapid developments in the information society where a concerted European approach is needed to protect the individual citizen and society as a whole. Smaller increases are also foreseen for nuclear safeguards, safety of civil structures and means of transport, protection of cultural heritage and the management of technological and natural emergencies. Against this growth a sharp decline is planned in our experimental research in nuclear fission reactor safety along with the termination of all work related to nuclear fusion.

The reorganisation of the JRC has given ISIS the opportunity to focus its research activities more clearly on its mission: namely the support of EU policy with systems oriented research where safety and security are of concern. The pharmaceutical and biotechnological regulatory activities now form central and growing aspects of the new Institute for Health and Consumer Protection, and industrial emissions research, a very successful spin-off from ISIS' nuclear programme is now a key theme in the Environment Institute.

The publication of this Annual Report illustrates an important milestone for the Institute, since it highlights an achievement in our collaborative research. Following the Council Conclusion of 26 April 1994 on the Role of the Joint Research Centre, it was for the first time in the Fourth Framework Programme, that JRC researchers could participate in the indirect research actions on an equal basis with European national institutions. We are proud to present our 81 collaborative projects, most of which are Shared-Cost Actions. The ensuing partnership comprises 350 organisations including industrial companies, universities and research centres. This provides us with access to a world class innovative network of collaborators and greatly enhances our ability to support our mission concerning EU policies. The reader will see that for all Shared-Cost Actions our participation represents activities strongly complementary to our institutional tasks.

The Institute is aiming to continue and extend the dynamic changes demonstrated during the Fourth Framework Programme and wishes to provide fast and flexible response to coming events. Our principal challenge will be to bring in to the Institute sufficient top quality staff in our main area of growth: namely information-related research. We are confident that the quality of our work will continue to attract such people, despite very strong demand in this labour market from industry.

I thank all our customers, partners and contractors for their confidence and support. I also thank every individual member of staff in ISIS for their continued efforts and innovativeness.

The Institute for Systems, Informatics and Safety is one of the eight institutes that constitute the European Union (EU) Joint Research Centre (JRC). The Institute's 350 staff, visiting scientists and students are based at Ispra, in the north of Italy.

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

ISIS supports EU policies with systems oriented research in areas where safety and security are of concern. Its prime objectives are to develop techniques for the assessment of risk in complex systems and to apply information, communication and engineering technologies for improving their reliability, safety and security.

The Role of ISIS

The Fifth Framework Programme moves ISIS towards its core mission. The Institute's technology base makes it ideally suited for supporting Commission policies related to the general theme of enhancing safety and security of the individual citizen and of society as a whole.

The expertise base from which this support is drawn is maintained by the participation in underpinning research, which is increasingly based on networks and joint projects together with European industry, universities and national research organisations. This research can be classified into a number of main themes:

- security and reliability in the information society;
- safety of building structures and means of transport and the protection of cultural heritage;
- safeguarding against the proliferation of nuclear materials;
- safety aspects of nuclear energy;
- fight against fraud;
- risk assessment and decision support.

The Application of Technology for the Protection of the Citizen and Society

Describing how ISIS's work programme is supporting EU policy and how the emphasis of the work is changing to reflect an evolving Europe

SECURITY AND RELIABILITY IN THE INFORMATION SOCIETY

The Commission believes that market forces must drive progress in the information society. EU policy is to provide an environment for such a market economy to flourish by encouraging interoperability and ensuring that the public is protected from the risks that accompany the benefits of advances in information technology.

ISIS will expand its work on information technology but, in keeping with the Commission's shift in emphasis, instead of focusing on the technology as an end in itself, ISIS will support efforts to improve the dependability of services. This will include support to DG XIII (Telecommunications, Information Market and Exploitation of Research) for the qualification of embedded systems, the application and demonstration of emerging networking technologies, the validation of medical telematics systems, and education multimedia. Research on information analysis for EUROSTAT will be complemented by a laboratory for dissemination of results and methodologies to national statistical institutes. ISIS supports humanitarian demining with information technologies and information management for mines infested regions, and data fusion for integrating signals from different sensors to identify landmines reliably without too many false alarms.

SAFETY OF BUILDING STRUCTURES AND MEANS OF TRANSPORT AND THE PROTECTION OF CULTURAL HERITAGE

European measures aimed at harmonising safety standards have the objective not only of lowering the risk of accidental death and injury but also of removing artificial barriers to trade.

Europe's first-line defence against earthquakes is Eurocode 8 which specifies design and construction standards for buildings and civil engineering works. ISIS provides the necessary background research for Eurocode 8 through ELSA, the reaction wall, a unique facility in Europe, which also supports the construction industry through the assessment of new innovative techniques for anti-seismic construction technologies.

For car safety there are a number of evolving European standards for crash resistance whose formulation provokes scientific debate among consumer groups and manufacturers. The large dynamic test facility (LDTF) helps the automotive industry understand how to meet present and future crash impact legislation.

Article 128 of the European Union Treaty authorises Community support to actions for the conservation and safeguarding of cultural heritage of a European importance. ISIS uses the ELSA reaction wall to analyse how buildings of architectural or historical importance can be protected from seismic damage and has developed three dimensional optical analysis techniques for the assessment of damage to structures and works of art.

ISIS will continue to apply its technology for the preservation of Europe's cultural heritage during the Fifth Framework Programme.

SAFEGUARDING AGAINST THE PROLIFERATON OF NUCLEAR MATERIALS

The EURATOM Treaty of 1957 empowers the European Commission to satisfy itself that fissile materials are not diverted from their intended use and collaboration agreements with IAEA were signed in 1977. New challenges are expected in the future from the entry into Safeguards of material released from

excess weapons and from the enlargement of the Union.
ISIS provides direct support to both DG XVII (Energy) and to IAEA (through DG I - External Relations: Commercial policy and relations with North America, the Far East, Australia and New Zeland) and also researches into techniques for meeting future requirements. The main areas of activity are in non-destructive assay, sealing techniques and remote surveillance. Based on experience of training inspectors at Ispra, a training centre at Obninsk in Russia has been set-up.
Safeguards work will continue with the same research activities and at approximately the same level as in the Fourth Framework Programme. Research will be started to determine whether satellites can be used for remote detection of illicit activities and to develop teleoperation and robotics techniques to allow surveillance with instruments installed at facilities to a distant safeguards office.

SAFETY ASPECTS OF NUCLEAR ENERGY

Each Member State is responsible for licensing its own nuclear reactors, and attempts to harmonise this procedure have, so far, been unsuccessful. Nevertheless nuclear energy provides 33% of Europe's electricity, the effects of severe accidents are not confined to one Member State and the Commission's nuclear safety research programme makes a major contribution to concentrating efforts in the Member States. The Commission has also promised that reactor safety will be an important consideration during the enlargement process.
ISIS provides direct support to DG XI (Environment, Nuclear Safety and Civil Protection) on various aspects of reactor safety whilst its research programme focuses on severe accidents. This has always been well integrated into the overall European effort both through its unique large facilities FARO, STORM and LDTF and also through its technical management, on behalf of the Commission, of the Phebus project. ISIS helps DG I with technical aspects of the TACIS programme and has successfully managed to involve partners in the central European countries in its research.
In the Fifth Framework Programme, ISIS's overall research on reactor safety will be reduced towards a carefully designed effort maintaining general competencies for policy support, and core scientific contributions to severe accidents research. FARO experiments with ex-vessel quenching of UO_2 based molten core material will reveal the long awaited effects of subcooled water. ISIS will continue to participate in the Phebus project with a presence on-site in Cadarache (France) and with code calculations. Studies on containment threats will concentrate on hydrogen risk modelling. Support to DG XI will cover benchmark exercises on judgement techniques and on dependability aspects of safety critical software.

FIGHT AGAINST FRAUD

The Member States are legally responsible for ensuring that the financial mechanisms of the Union are not defrauded. Nevertheless it can be politically difficult for them to do so and an overview at European level is sometimes necessary, especially in cases of cross-border fraud.
During the Fourth Framework Programme ISIS has greatly expanded its work in support of EU bodies, especially UCLAF and DG VI (Agriculture), that have a responsibility for helping Member States combat fraud. The activities mainly involve electronic tagging schemes for animal identification, information and communication technology and statistical analysis.

RISK ASSESSMENT AND DECISION SUPPORT

The European Union's Fifth Environmental Action Programme calls for shared responsibility between government institutions, business and the public. Communication between main actors is the tool to move cohesion beyond common regulations and controls.
ISIS supports these goals applying state-of-the-art Information and Communication Technologies (ICT), integrated assessment, development of decision enhancement tools, and research on participatory decision processes on environmental issues. Learning from events, Europe wide, contributes to harmonisation of safety and environmental policies. MAHB, the Major Accident Hazards Bureau, fosters the implementation DG XI's Seveso 2 directive. ECCAIRS enforces the policy of DG VII (Transport) to share information about aircraft incidents.
These activities will be strengthened during the Fifth Framework Programme with additional information exchange centres for DG XI focussing on natural and technological hazards. Basic research on decision enhancement technologies will focus on sustainable mobility. Further applications will be decision support to urban policy-making, integrated coastal zone management, and strategic water resource management for water quality and drought/ flood issues.

Contents

X Shared-Cost Action projects within the Fourth Framework Programme. The partners for each project are listed on pages 120-123.

Information Society

editor: G. Mancini

Following the European Commission Programme Activity "Creating a User Friendly Information Society", ISIS has focused its research in the area of "Benefiting from the Information Society", where emphasis is given to the customers' needs and benefits in the emerging Information Society.

The ever-growing networking capabilities provided by Internet, and the convergence of communication and information technologies have led to enormous possibilities for the user but also to an increasing demand of confidence and security.

ISIS has therefore defined and investigated such information and communication attributes as: dependability, trustworthiness, easy access and processing for important societal applications related to health, elderly and disabled persons, education and training and electronic commerce.

Information dependability

author: M. Wilikens

ISIS carries out research, development and provides scientific support in the field of dependability of systems and services that are critical for safety, mission and security aspects.
The main customer of its work is DG XIII (Telecommunications, Information Market and Exploitation of Research), the Directorate General responsible for the Information Society Technologies (IST) programme. Activities in 1998 have focused on co-ordinating the definition of the European Dependability Initiative within the EC's Framework 5: IST programme. The work consisted in preparatory studies and consultation with over 50 organisations for identifying dependability challenges and a research agenda for the deployment of new services and systems that use large-scale information infrastructures and extensively deployed embedded systems. Work in 1998 also started on the development of TRINIDAD (Trial Infrastructure for Information and Dependable Application Deployment) (Figure 1.1). The infrastructure is designed to provide trials of innovative dependability and security technologies. It will also include networking facilities to allow collaborative remote access to the infrastructure and project specific information and to allow the inclusion of remote nodes to emulate extra-net and wider global networks. One of the most important applications of the dependability technology is certainly constituted by the Electronic Commerce. An initiative has been creating a cluster of projects, at the JRC level, dealing with related issues.

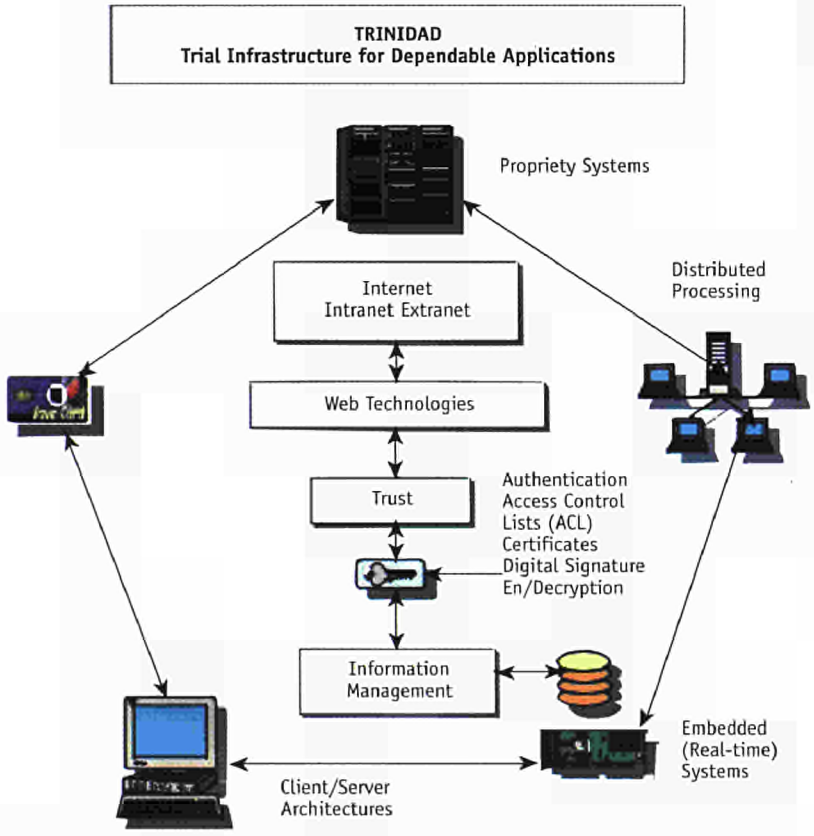


Figure 1.1: Scheme of the Trial Infrastructure for Information and Dependable Application Deployment (TRINIDAD) infrastructure.

Multi stages – multi enterprise logistic control system (MUSSELS)

ISIS contact: M. Wilikens

MUSSELS is an ESPRIT project within the Integratio in Manufacturing projects cluster. MUSSELS is to pro duce a tool capable of overcoming the problems as sociated to traditional production planning and cor trol systems. This increases the co-ordination leve between the actors of the logistic chain, and enable them able to act as a virtual enterprise. During 199E the role of ISIS in the project has been focused o the provision of the general model, including th business process modelling aspects. The Institute long-term interest in MUSSELS is in gathering de pendability requirements for information infrastruc tures within large-scale virtual enterprises.

References

[1.1] Wilikens M., Morris P. (Eds.). Dependability of Large-scale infrastructures and services in the Information Society. Report of the Thematic Worksho held on 18th March 1998 in Brussels. European Commission report, EUR 18070 EN, 1998.
[1.2] Masera M., Wilikens M., Morris P. (Eds.) European Dependability Initiative: Extensively Deployed and Networked Embedded Systems. Report of th Thematic Workshop. European Commission report, EUR 18069 EN, 1998
[1.3] Wilikens M., P. Morris, M. Masera (Eds.) Defining the European Dependability Initiative. A strategy document. EUR Report 18139, 1998

2 Improving the industrial decision making process through experience feedback (NOEMIE)

ISIS contacts: M. Atkinson, J.P. Nordvik

Corporate knowledge of large industrial companies exists in many formats and is often stored in dedicated databases scattered in diverse physical locations. The 3-year Esprit project NOEMIE (New Object Environment for the Management of Industrial Experience) has developed a methodology and tools to reuse such knowledge to improve the efficiency of co-operate decision making process across different departments and working disciplines.

Together with traditional database interrogation mechanisms, the NOEMIE project has exploited and integrated Data Mining (DM) and Case Based Reasoning (CBR). ISIS' major contribution focused on the construction of an architecture for the definition and exploitation of a domain-oriented knowledge base. It provides a common base for integrating all pertinent information for decision-making from both a software system and user perspective. The architecture integrates the structure and nature of available historical data, a general domain model for the representation of the user decision problem, and data analysis tools.

A distributed client-server software application was used in NOEMIE. This application consists of a central controller that integrates plugged-in tools such as legacy databases (via a data warehouse), free text retrieval tools, data-mining tools (Clusters and Bayesien Networks), Case Base Reasoning tools (both data oriented and knowledge intensive) and standard database query engines. The complete system was constructed in the Java programming language using World Wide Web technologies to allow multi-user distributed access.

The user interface, integrated into traditional Web Browsers, combines the standard techniques for browsing and navigation with a wizard oriented approach to aid the user in the complex process of problem solving and experience reuse; Figure 1.2 (a) and (b).

Two industrial applications were developed to validate both the methodology and the software system against real-world cases. The first application focused on information retrieval across corporate databases for determining the reliability, both mechanical and financial, of oil industry borehole instrumentation. The second application focused on real-time diagnosis to prevent unwanted events during oil drilling operations.

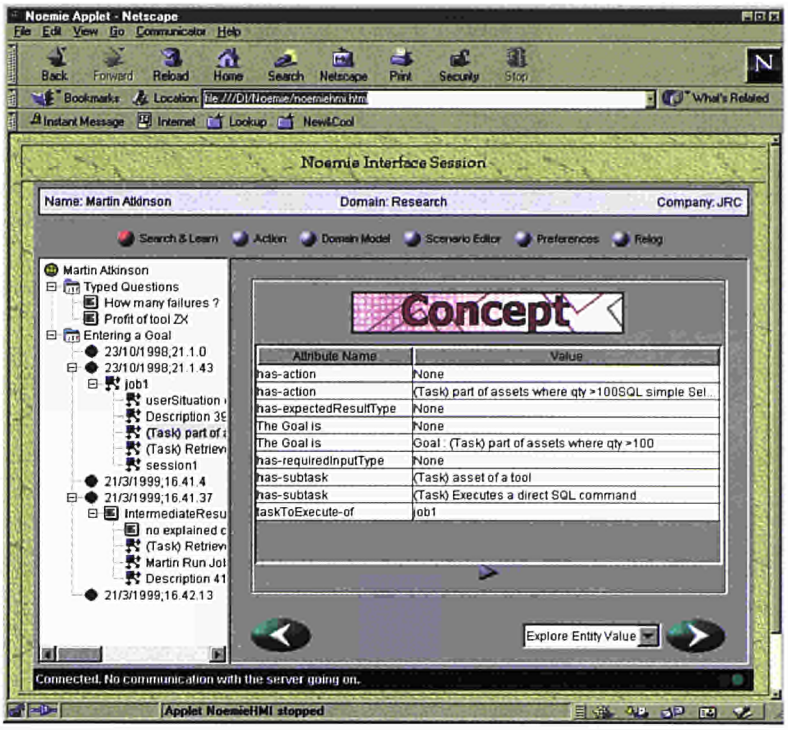


Figure 1.2 (a): Example of a screen of the NOEMIE internet wizard for problem-solving assisted data-retrieval. Integrated into an Internet browser the left pane traces the history of the user interactions; the right pane allows the user to capture the principal concepts related to the problem space.

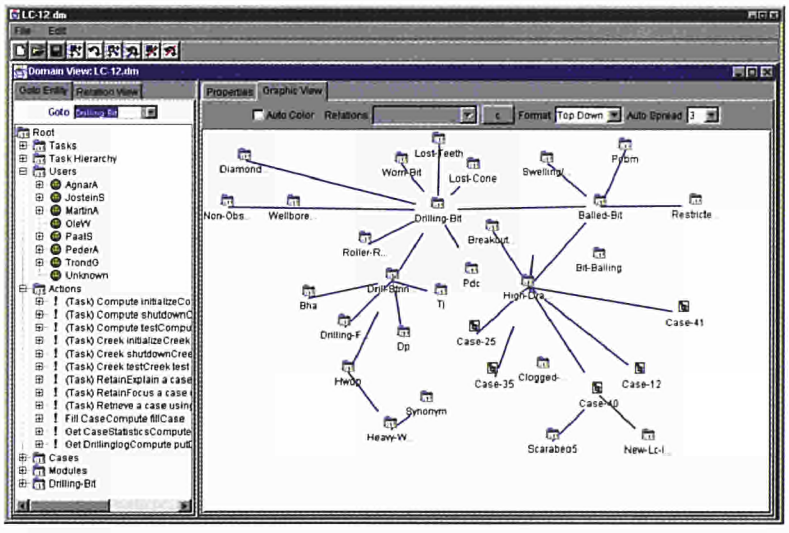


Figure 1.2 (b): Main screen of the NOEMIE domain model editor for the management of all information related to the user application. The left pane shows a hierarchical classification of the principal entities of the domain model. The right pane represents graphically the various relationships existing for a selected entity.

3 Promoting Requirements Engineering from Current Engineering PracTices (PRECEPT)

ISIS contact: P. Morris

PRECEPT (an ESPRIT project) is to develop a system requirements elicitation method and support tool. It has two main objectives; commercial (to reduce production costs, reduce time to market and improve product dependability) and technical (to improve the requirements elicitation process, make the process more customer driven and customer sensitive and to ensure the developed techniques are fully compatible with current industrial practices and techniques). ISIS is in charge of the technical management of the project and of the special interest group of industrial end-users.

Education multimedia

author: C. Best

Global Educational Multimedia server – GEM

ISIS has built GEM under a competitive contract with DG XIII for the Multimedia Education Taskforce of the European Commission. The concept of GEM is to develop a European scale clearing house of information, products and services in the domain of emerging multimedia technology applied to education and training. Many teaching institutions and companies are already pursuing the vision of a new educational model based on high-speed networks, multimedia content and distance learning. The difficulty facing suppliers and users of such systems is to find existing services, planned services and general information. This need is likely to increase greatly in the future as the market begins to expand. One of the needs will be to help teachers and potential students to discover each other and to put providers and customers in touch.

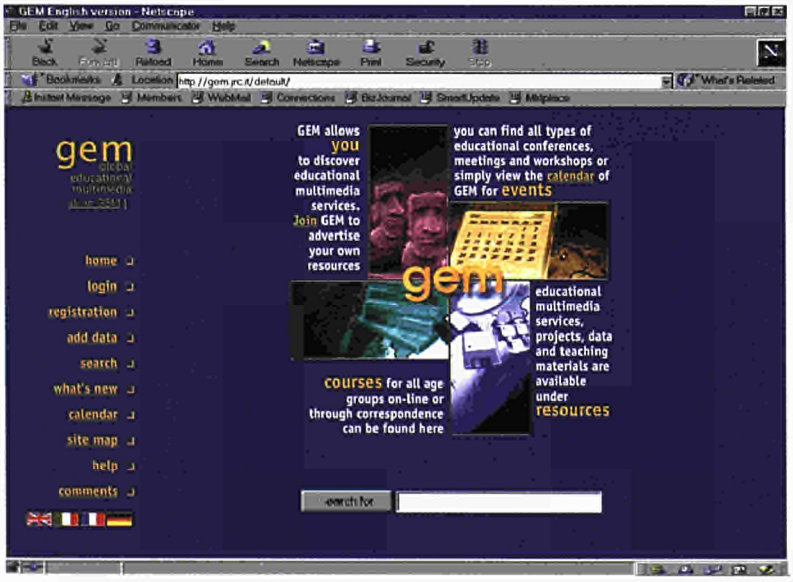


Figure 1.3 shows the entry page of the Global Educational Multimedia Server (GEM) at http://gem.jrc.it. 10,000 people have accessed this page during 1998.

GEM is conceived as a dynamic database accessible through the Web (Figure 1.3), whose information and data content are submitted and updated by the suppliers, teachers and to some extent students. It aims to be a focal point in Europe for locating information and services in this growing domain. GEM allows any Internet user to search for courses, educational products and educational events either through simple free text or classified by thematic keywords and media types. However GEM is more than an ordinary Web site. Users and organisations, students and teachers, providers and customers can register on the system. After registering, users can "advertise" products if they are providers or requests for services if they are users. Similarly Jobs, conference notices and courses can be announced. Each item of information entered by a user can be modified on-line by that user. There will soon be discussion groups and Fora provided with the system. It is possible to upload multimedia content (images, audio and video) from the users PC to the database. GEM will also be able to host full interactive courses in a general framework. A database design and Web interface will be implemented that can allow for a general course framework. This framework allows students to register for courses and teachers to monitor progress. At this stage the system is envisaged as a solution for small organisations without the facilities to run their own distance learning courses, but will be able to use GEM to host them. Future developments envisage a federation of servers coupled through GEM.

GEM is currently available in pilot operations. New functionality is planned and will be added over the next year. The hosting of course material through a structured course database is under design. Each course can be updated by the author/maintainer, and a database of registered students will be available to the maintainer. Discussion groups, bulletin boards and virtual meetings are in preparation. Linkages to other systems through search interfaces based on Z39.50 are planned, as well as through standard http interfaces. The user interface will be reviewed and updated in the light of user feedback, and new requirements of the European Commission.

4 A student's Parliament via educational multimedia learning models and technologies (ParlEuNet)

ISIS contact: C. Best

ParlEuNet is framed in the Educational Multimedia Task Force Joint Call for Proposals. ParlEuNet will serve as a multimedia educational platform that will allow the evaluation of innovative tutoring models in a rich telematic learning environment. The results will provide essential input for full-scale implementation of multimedia learning models in European schools. The ParlEuNet project is a network around the European Parliament consisting of a structured information database and a collaborative working space. ParlEuNet will enable pupils to collaborate on joint projects and, in the process, enhance their understanding of the European Parliament. It is the first Europe-wide initiative to put state-of-the-art technology at the disposal of schoolchildren and let them collaborate over the Internet (Figure 1.4). The emphasis will be on student-based learning, a collaborative approach and turning users into providers so that everyone's experience and knowledge is fully used. Students can link up using Internet connections and videoconferencing. At first, they will use the material on the site itself but, gradually, their own work will supplement this material as they develop educational modules and resources themselves.

5 ATM and telecollaborations for research and education (ATRE)

ISIS contact: E. Blockeel

ATRE built and experimented a platform running IP (Internet Protocol) and IPv6 over ATM (Asynchronous Transfer Mode) for telecollaborations and teleseminars between several European research communities.

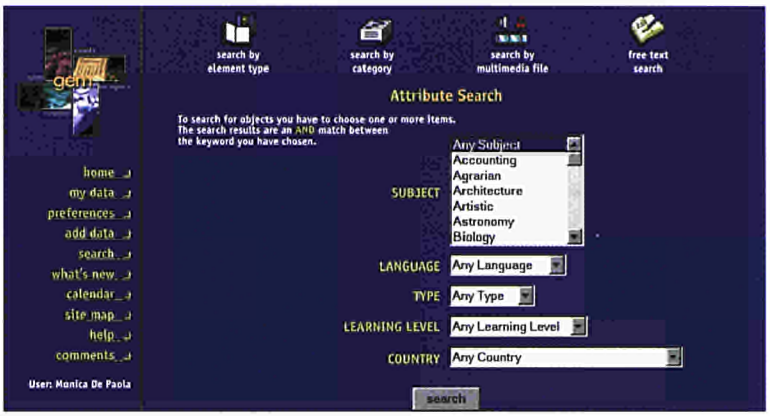


Figure 1.4: Collaborative Web Space - ParlEuNet http://saur.jrc.it:1080/posters/PEN2.tif, a pilot project for European schools.

European statistics

authors: A. Saltelli, C. Planas, K. Chan

Support to the European Statistical Office

EUROSTAT (the statistical office of the European Union) is an authoritative source of information on the state of the union, and on the pace of economic and political evolution toward the single market and currency. In collaboration with national statistical institutes (NSI), EUROSTAT collects, consolidates and harmonises statistics that are relevant to all EU policies. The enhanced climate of collaboration between the JRC and EUROSTAT developed in the past two years has led to a Memorandum of Intent, signed by the Directors General of the two DG's in June 1998, to set-up the European Statistical Laboratory (ESL). ISIS operates ESL under the "Creating a user-friendly information society" section of the European Commission's Fifth Framework Programme. ESL role includes the dissemination of concepts, tools and practices to and across national statistical institutes, monitoring technological developments in statistics, assisting NSI's on training and facilitating the exchange of research personnel. This includes the secondment of national experts within the network and staff exchanges occurring between Ispra and Luxembourg. While dissemination and networking constitutes one main pillar of ESL's activity, another is its research work, mostly by the execution of competitive activities. These include:

- the evaluation of sensitivity and uncertainty analysis methods in Official Statistics (see Sensitivity Analysis)
- the use of Neural networks for data analysis (see Neural Networks)
- the analysis of economic time series, for seasonal analysis, trend extraction and forecasting [1.4-1.7]; see http://www.jrc.org/isis/sa/activities/time-ser/
- spatial analysis of interregional migration (using EUROSTAT's GISCO and REGIO databases)

Another relevant development project focuses on the access to, interchange and visualisation of statistics-related information (see *Multi-user Virtual Reality*).

Sensitivity analysis

Sensitivity Analysis (SA) aims to ascertain how a given model (numerical or otherwise) depends upon the information fed into it. SA is a prerequisite for model building in any setting - be it diagnostic or prognostic - and any field - be it mathematical, natural or social sciences - where models are used and developed. The JRC, though its laboratory at ISIS, is among the most advanced in the field. (see www.jrc.org/isis/sa/activities/uasa/). It organised a major conference (with the University of Venice) in April 1998 in Venice: SAMO98, the Second International Symposium on Sensitivity Analysis of Model Output (see ISIS five contributed papers in [1.8]). The proceedings [1.8] can be ordered at JRC-ISIS (see www.jrc.org/isis/sa/activities/summer_school/). A special issue of the journal Computer Physics Communications devoted to the event [1.9] (see www.jrc.org/isis/sa/activities/special_issue/).

In the course of 1998, ISIS completed a negotiation with the editor John Wiley and Sons for the publication of a large handbook on sensitivity analysis [see www.jrc.org/isis/sa/activities/SAbook/], the first ever devoted to this topic. The volume, with several chapters contributed by ISIS and EUROSTAT, is expected to appear in early 2000, and it will be tested for a summer school to be held in Venice in July 1999 [see www.jrc.org/isis/sa/activities/summer_school/]. SA work in 1998 focused on methodology [1.10-1.14] and applications [see also GESAMAC, 1.15-1.19]. DG XIII-B (Advanced Communications Technologies and Services) contributed in 1998 to the dissemination of ISIS software for sensitivity analysis (PREP-SPOP, see www.jrc.org/isis/sa/activities/prep_spop/) and renewed its support for 1999. One major development of ISIS in 1998 in the SA domain is the "Evaluation of Sensitivity and Uncertainty Analysis Methods in the Quality Assessment Framework with Application to Environmental and Business Statistics" [see www.jrc.org/isis/sa/activities/Lot14/]. This project investigated the improvement that can be achieved using SA in measuring the quality of statistics [1.19].

In parallel, a study was run to test the use of SA in the statistical analysis of economic time series. The attention focused on seasonal adjustment and trend extraction. Sensitivity analysis has been found a useful tool for model assessment: it fits with the sake of model parsimony, it is complementary to standard tools like the Bayesian Information Criterion, and it gives messages about quality of model definition that standard statistical tests do not deliver.

[1.4] Planas C. The Analysis of Seasonality in Economic Time Series: A Survey of New Developments. *Research in Official Statistics*, v.1, n.1, pp. 51-64, 1998.

[1.5] Depoutot R., Planas C. Finite Approximations to Infinite Filters and the Monitoring of Revisions. In Proceedings of *New Techniques and Technologies for Statistics*, Sorrento, 1998, Vol. 1, pp. 145-150, 1998.

[1.6] Planas C. Linear Signal Extraction with Intervention Techniques in Non-linear Time Series, Journal of Forecasting, 17, 515-526, 1998.

[1.7] Fiorentini G. and Planas C. From Autocovariances to Moving Average: An Algorithm Comparison, Computational Statistics, 13, 477-484, 1998.

[1.8] Chan K., Tarantola S., Campolongo F. (Eds) *Proceedings of the Second International Symposium on Sensitivity Analysis of Model Output (SAMO98)*, Venice, Italy, April 19-22, 1998, EUR report 17758 EN, Luxembourg 1998, ISBN 92-828-3498-0, 1998.

[1.9] Saltelli A., Chan K., Scott M. (Eds) Special Issue on Sensitivity Analysis. *Computer Physics Communications*, 117, 1999.

[1.10] Saltelli A., Bolado R. An Alternative Way to Compute Fourier Amplitude Sensitivity Test (FAST). *Computational. Statistics and Data Analysis*, 26(4) pp. 445-460, 1998.

[1.11] Saltelli A., Tarantola S., Chan K. Presenting Results from Model-based Studies to Decision-makers: Can Sensitivity Analysis be a Defogging Agent? *Risk Analysis*, Vol. 18 (6), pp. 799-803, 1998.

[1.12] Campolongo F., Braddock R. The use of graph theory in the Sensitivity analysis of the model output: a new screening method, Reliability Engineering and System Safety, 64, 1-12, 1999.

[1.13] Saltelli A., Tarantola S., Chan K. A Quantitative Model Independent Method for Global Sensitivity Analysis of Model Output. *Technometrics*, 41 (1), 39-56, 1999.

[1.14] Saltelli A. Sensitivity Analysis. Could Better Methods Be Used? *Journal of Geophysical Research*, Vol 104 (D3), pp 3789-3793, February 20, 1999.

[1.15] Campolongo F., Tarantola S., Saltelli A. Tackling Quantitatively Large Dimensionality Problems. *Computer Physics Communications*, 117, pp 75-85, 1999.

[1.16] Campolongo F., Saltelli A,. Jensen N.R., Wilson J., Hjorth J. The Role of Multiphase Chemistry in the Oxidation of Dimethylsulphide (DMS). A latitude Dependent Analysis. *Journal of Atmospheric Chemistry*, 32, pp 327-356, 1999.

[1.17] Pastres R., Chan K., Solidoro C., Dejak C. Global sensitivity analysis of a shallow-water 3D Eutrophication model, Computer Physics Communications, 62-74, 1999.

[1.18] Draper D., Pereira A., Prado P., Saltelli A., Cheal A., Eguilior S., Mendes B., Tarantola S. Scenario and parametric uncertainty in GESAMAC: A case study in Nuclear waste disposal risk assessment, Computer Physics Communications, 142-155, 1999.

[1.19] Tarantola S., Puolamaa M., Jesinghaus J., Saltelli A. Global Sensitivity Analysis: A Tool For Environmental Modelling Quality Assessment. *In Proceedings of New Techniques and Technologies for Statistics*, Vol. 2, pp. 509-514, 1998.

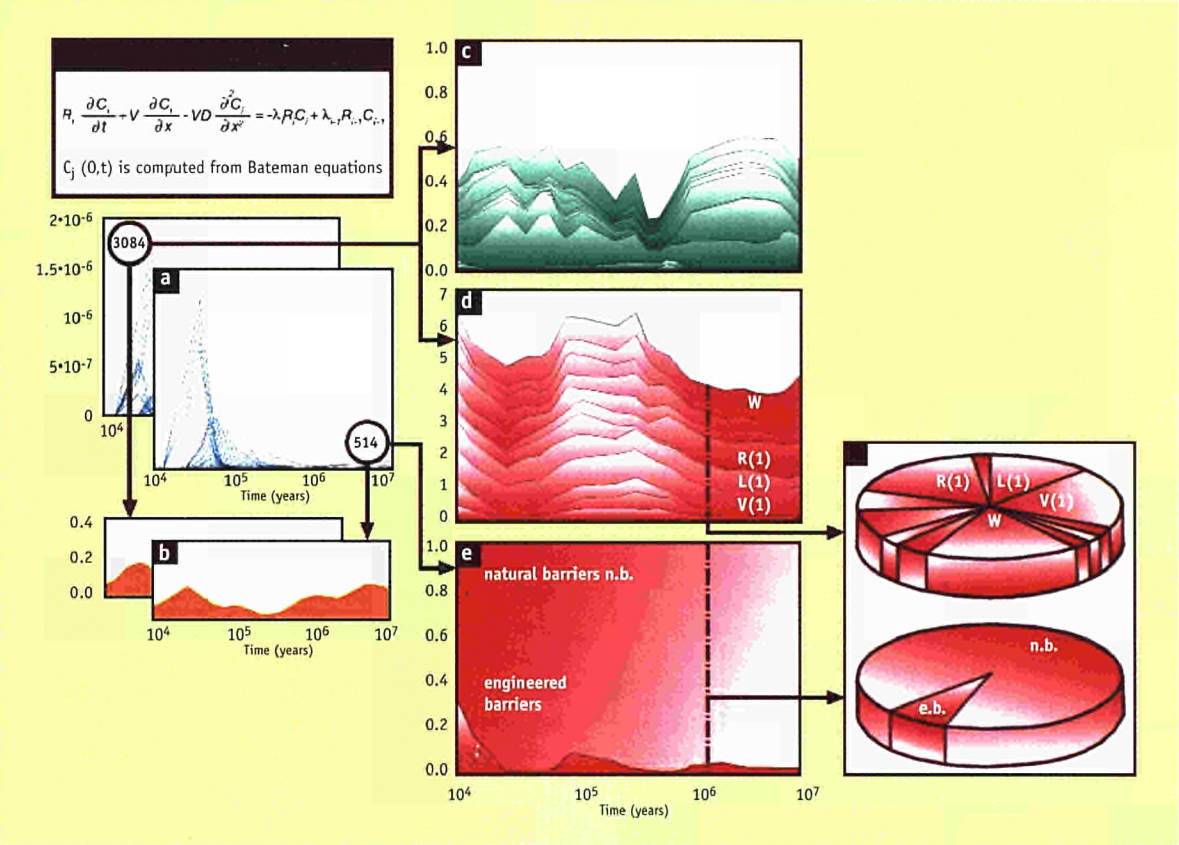


Figure 1.5: Output from sensitivity analysis for the GESAMAC exercise. The curves displayed in (plot a) are the results of the model evaluation. They have been used both for estimating the model coefficient of determination R^2 (plot b) and for decomposing the variance of the output. Plots (c), (d), (e) are different sensitivity measures for the input factors as function of time. Plot f is a cut at a given time. In (e) the sensitivity has been measured by dividing the factors in just two sets (natural and engineered barriers).

6 *Geosphere modelling, geosphere sensitivity analysis, model uncertainly in geosphere modelling, advanced computing in stochastic geosphere simulation (GESAMAC)*

ISIS contacts: A. Saltelli, S. Tarantola

GESAMAC is part of the Nuclear Fission Safety Programme, DG XII/F. Conceptual and computational tools are developed to tackle parametric and structural model uncertainties as well as sensitivity analysis in environmental assessment, see www.jrc.org/isis/sa/activities/gesamac/). The methods were applied to a nuclear disposal safety analysis case study.
ISIS task in this project was to develop a new more powerful sensitivity analysis tools for model output. This is based on Fourier Amplitude Sensitivity Test (FAST) and the results (Figure 1.5) will be published on Technometrics in 1999 can be found in [1.18].

Neural networks

author: A. Varfis

The first mission of the Statistical Office of the European Communities (EUROSTAT) is to provide the European Union with reliable statistical information for supporting common policies. Neural Network (NN) technologies offer a set of flexible models and methods to address relevant tasks in data analysis, knowledge extraction and statistical modelling. In 1998, the Neural Network Laboratory (NNL) of ISIS was involved in two Support to the Commission activities: Casualty analysis between production-index time-series and qualitative indicators and Economic data nowcasting. Each of these comprises two distinct parts.
Causality analysis between production-index time-series and qualitative indicators was completed in 1998. An original approach, based on a combination

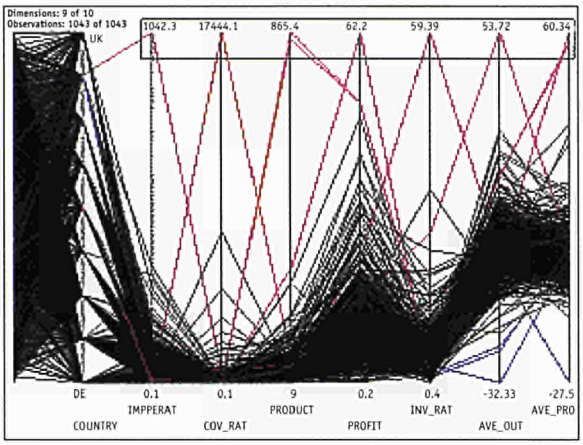


Figure 1.6: Parallel co-ordinates representation as a tool for data analysis of the 1995 European Industry data [from http://europa.eu.int/en/comm/eurostat/research/intro-en.htm].

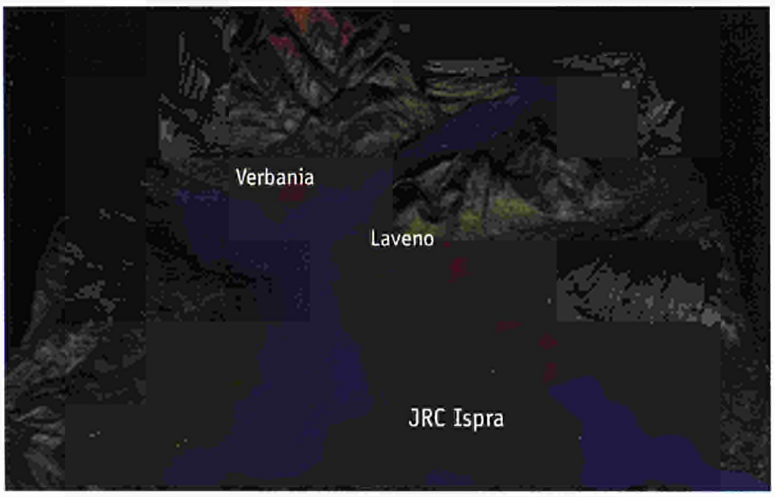


Figure 1.7: 3D model of Lake Maggiore (Italy) implemented in the Virtual Reality Modelling Language (VRML97). The model is based on digital elevation data textured with satellite imagery.

of dynamic programming and NN techniques, gave insight into the lead-lag structure relating quantitative series of industrial production indexes to qualitative indicator series issued from a business climate survey. Within this project, there was the Transport Data Analysis section where the key issue was data quality. A prototype software combining conventional and neural network techniques, has been developed for outliers detection in the large database of transport data.

The Economic data nowcasting project started in 1998. Neural network models are being developed as an alternative to conventional time-series analysis techniques in a system of flash estimates of the main quarterly national accounts aggregates of the EU Member States. An extension of this study is the NN for Transport Data Analysis where heterogeneous databases are considered.

Statistical data visualisation techniques

authors: V. Alexandrou, S. Arsenis

In 1998 ISIS concluded a project on using parallel co-ordinates visualisation for the analysis of large, statistical, multidimensional data sets. In parallel co-ordinates visualisation, the values of the variables are represented on parallel equidistant lines (the parallel co-ordinates) and broken lines intersecting the parallel co-ordinates therefore represent multivariate observations.
This work was conducted as part of the tendering cycles SUPCOM96/Lot.30, in consortium with Atkosoft S.A. (GR), the software developer who implemented the parallel co-ordinates representations on PCs. Such representations were applied to two data sets provided by EUROSTAT: the European Industry data (Figure 1.6) and the COMEXT data on bovine trade flows. In conclusion (see http://europa.eu.int/en/-comm/eurostat/research/intro-en.htm.), parallel co-ordinates allow the identification of outliers and clusters present in the data.

Multi-user virtual reality

author: P.A. Loekkemyhr

During 1998 two Virtual Reality (VR) research projects in have been completed.
The first, carried out under a contract in the HPCN (High Performance Computing and Networks) programme of Esprit, is based on research and assessment of multi-site applications of Virtual Reality. The results fall into two categories: through a survey into requirements, state-of-the-art and future directions of distributed Virtual Reality and through a set of demonstrators developed specifically to exploit new and emerging technologies in this domain. The demonstrators and survey reports are available to the public on the project web-site: http://vr.jrc.it, Figure 1.7.
The second project, in support to EUROSTAT, is a virtual with a set of buildings and rooms tailored to establish a metaphor of everyday life. People and researchers can meet and mingle face to face with fellow colleagues in a 3D multi-user space and can discuss matters of interest without leaving their offices. In addition real-world conference events can be web-cast to enable a broader audience to attend. A dynamically updating 3D library is also present to help users browse, read and submit documents.
The Virtual Reality Modelling Language (VRML) together with Java provides the interface for virtual

meetings and conferences within 3D multi-user worlds. Audio and video technologies have been added to improve the feeling of presence for the user. The results are available on the project web-site http://vesl.jrc.it, Figure 1.8.
This work has been carried out at a crucial period in the development of distributed virtual reality. There is an increasing interest in the real-time combination of real and simulated (i.e. VR models) data. Future applications for these augmented VR models are remote inspection, tele-operation and training [1.20, 1.21].

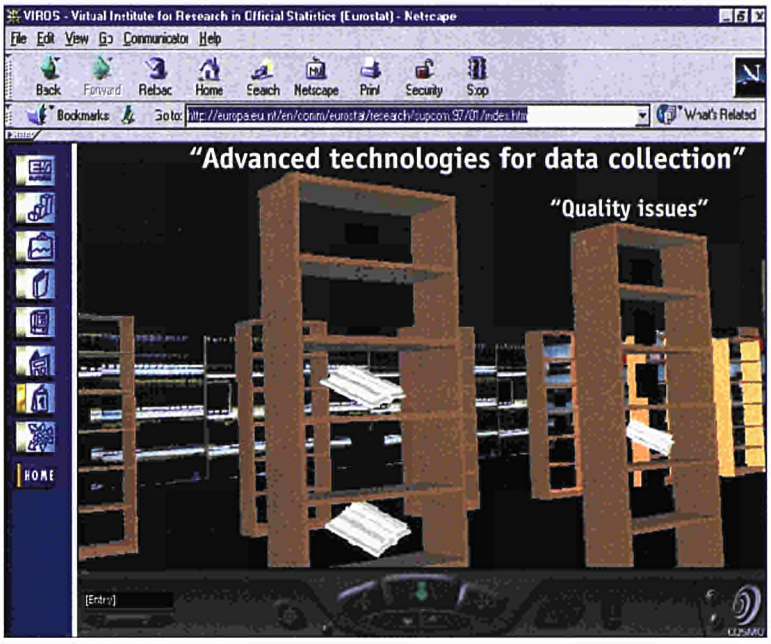


Figure 1.8: A dynamically updated Virtual Library implemented in VRML97 and Java. A Java-applet sends out queries for documents to many search-engines. The hits are filtered, organised and represented in the shelves as books.

Three-dimensional medial imaging

authors: L. Portoni, A. Patak, P. Noirard, J.-C. Grossetie

The availability of the huge amount of information provided by the data sets of the Visible Man and Woman offers to medical and bioengineering professionals as well as researchers possibilities that were previously unimaginable. 3D models of any anatomical structure of the human body can be generated with the Visible Human Data-set (VHD). 2D images and 3D models can be used to teach future physicians,

Figure 1.9 (a): Reconstruction of the female lumbar vertebrae using the Marching Cubes Algorithm from computer tomography (CT) images (1 slice/mm).

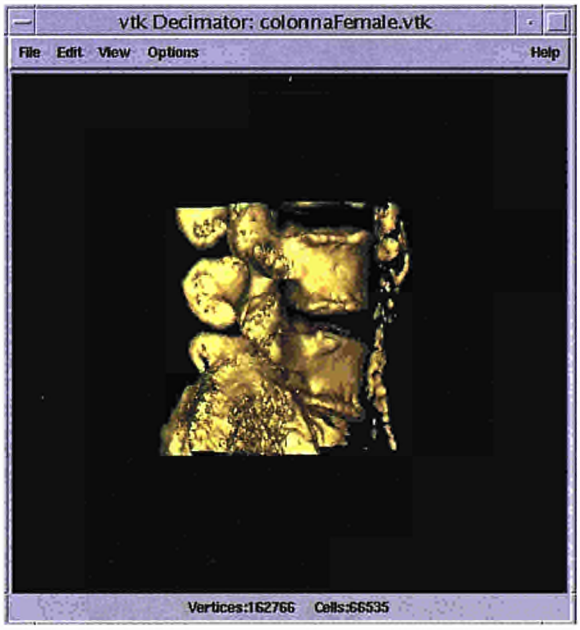


Figure 1.9 (b): Reconstruction of the female abdomen skin using the same algorithms as in Figure 1.9 (a).

[1.20] Guittet C., Best C., Loekkemyhr P., Schickel P. The Virtual European Statistical Laboratory. Paper presented at *Conference New Techniques & Technologies for Statistics*, Sorrento, Italy, November 1998.

[1.21] Guittet C., Best C., Loekkemyhr P., Schickel P. *A Shared Virtual World: The Virtual European Statistical Laboratory*. Paper presented at the *Online Information '98 International Conference* in London, December 1998.

to simulate of interventions, to navigate inside the human body, to develop computer-aided surgery tools and environment, and to increase the understanding of human anatomy.
The 3Dimage Processing and Synthesis laboratory (3DIPS) at ISIS started to work in this field using the images of the VHD. In 1998 the entire VHD was completed and tested on the Silicon Graphic system.
To perform image processing and 3D reconstruction the Visualisation Toolkit (vtk) has been used. By using the interpreted Tcl/Tk application layer supported by the vtk, 2D images of the VHD generated 3D models of different anatomical structures. A freely available C++ class library for 3D graphics and visualisation. This choice guarantees portability across PC and Unix systems. The vtk C++ library consists of over 500 classes; vtk supports techniques for scalar, vector and tensor visualisation. Modelling algorithms such as decimation, implicit modelling, extrusion, texture cutting, Delaunay triangulation, and others, are also available. Figures 1.9 (a) and 1.9 (b) display two interactive windows containing reconstructed 3D models of structures generated from the Visible Female data at ISIS.
The visualisation toolkit supports OpenGL rendering libraries. The tcl/tk user interface allows one to visualise generated 3D models through a powerful interactive window enabling the user to change surface properties; to perform triangulation, decimation, smoothing procedures; to change the light of the scene; to zoom in and out the displayed object; to rotate it; and to save the 3D model file in different formats such as Virtual Reality Medical Language (VRML) or stereo-lithographic formats.

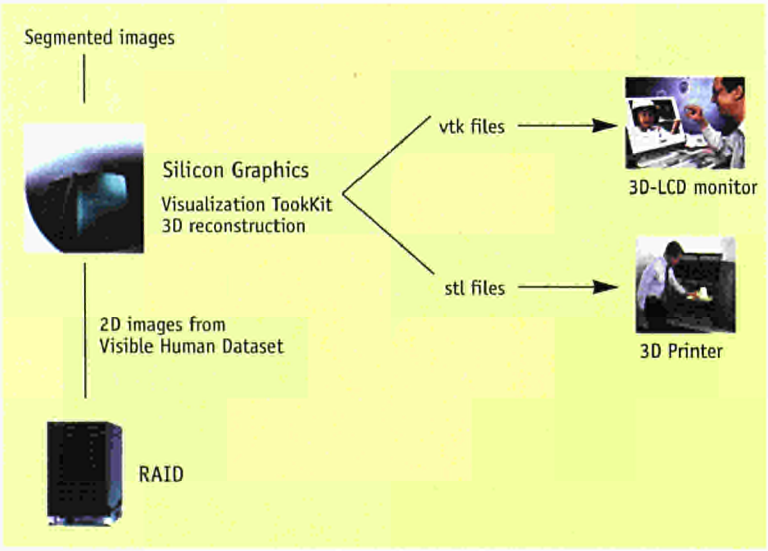


Figure 1.10: The 3D image Processing and Synthesis laboratory (3DIPS) scenario. This system uses 2D images that through 3D reconstruction techniques become real 3D-image visualisation. Solid 3D models can then be generated for numerous medical applications.

To obtain a stereoscopic three-dimensional image visualisation, the Silicon Graphics Octane has been connected to an innovative auto-stereoscopic 3D-LCD monitor developed within a collaboration of JRC and Philips (UK). The optic technology on which this special monitor is based allows the user to have a real 3D perception of the displayed objects without the need to wear special glasses. Some new C++ classes, developed by ISIS, have been implemented and added to the visualisation toolkit library to fully exploit the features offered by the auto-stereoscopic screen in volume rendering.
ISIS installed a GENISYS 3D stereo-lithographic system dedicated to 3D imaging. This opens up the way to the use of rapid prototyping technologies in medical field. 3D models generated with the visualisation toolkit can now be easily transformed in stereo-lithographic format (stl) and used as input files for the GENISYS 3D system.
Actually, the working environment available in the 3DIPS laboratory and mainly dedicated to 3D medical imaging can be sketched out as in Figure 1.10.

Fluorescence imaging for *in vivo* diagnosis of pancreatic disease

author: M. Whelan

The two main chronic diseases that attack the human pancreas are pancreatic cancer and acute pancreatitis. These particular diseases are almost incurable and current statistics put the five years survival for human pancreatic cancer at less than 5%, while less than 48% of acute pancreatitis sufferers can be expected to be rendered disease free, whatever the kind of treatment administered. The prognosis for these two conditions or pathologies strongly depends on early diagnosis. Also, any course of potentially life-saving treatment is inherently linked to the stage at which the disease is identified. In present clinical practice, modern CT (Computed Tomography) scanning and NMR techniques are the more recognised diagnostic tools for pancreatic cancers. However, neither technique can detect a tumour less than 1 cm in size, at which stage the patient's condition is already critical. The current diagnosis of pancreatitis is based on a method that takes into consideration a number of weighted clinical and biochemical parameters to yield what is known as the Ranson Score. However, CT scanning is the only efficient way of assessing a strong pancreatic necrosis, unfortunately the latest stage of the disease and beyond treatment.

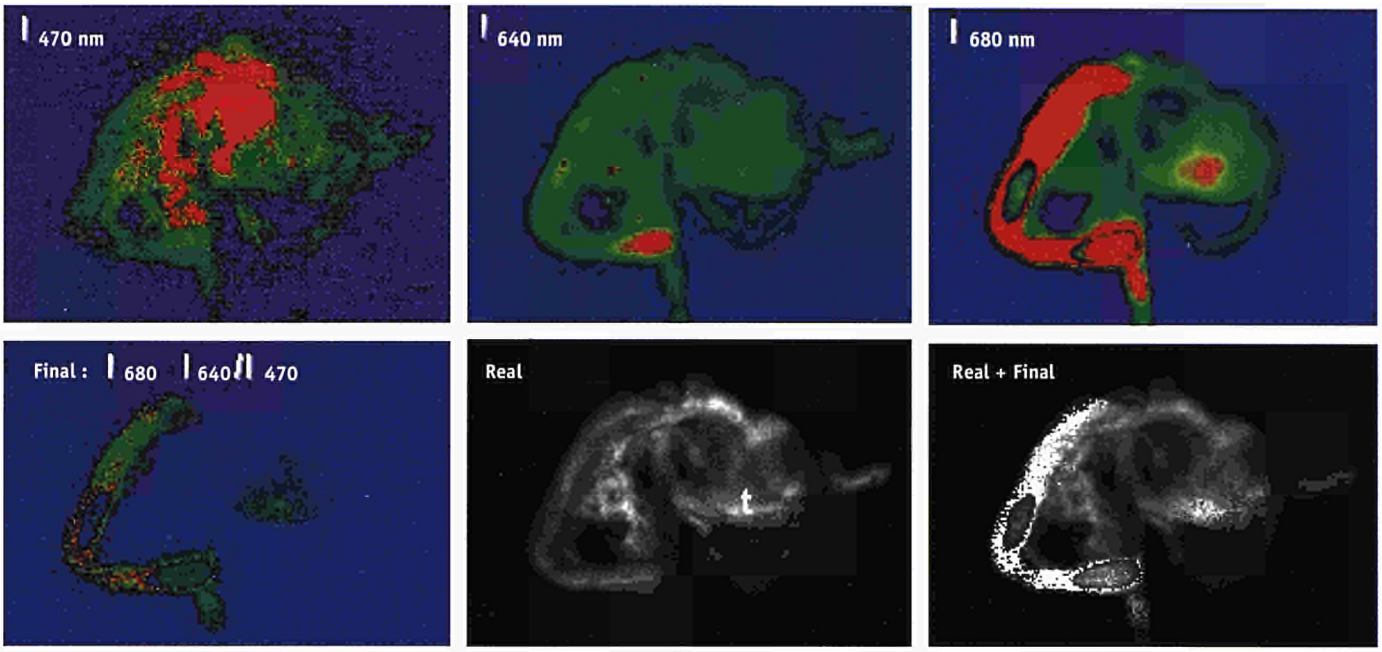


Figure 1.11: Fluorescence imaging of rat pancreas at various filtering frequencies and ratiometric image analysis for detection of cancerous tissue.

Recently, however, ISIS has developed a powerful diagnostic tool for the early detection of chronic pancreatic disease based on laser induced fluorescence spectroscopy (*European Patent # PCTFR98/01950*). All living tissues emit fluorescent radiation under appropriate light excitation, this property being linked to the presence of endogenous fluorophores in the extra cellular matrix (these fluorophores are biochemical intermediates of the mitochondrial respiratory pathway). Any changes in extra cellular matrix composition and/or mitochondrial activity, induced by disease, lead to a change in the fluorescence properties of the pancreatic tissue (i.e. spectral distribution, intensity). By detecting these changes (e.g. using spectral analysis) early, accurate diagnosis of pancreatic disease is possible.

The 1998 Exploratory Research Programme of ISIS has supported the design and construction of a laboratory prototype system and a study related to the identification of optimum excitation wavelengths for maximising the stimulated fluorescence of pancreatic tissue. A ratiometric approach to fluro-spectra analysis has been developed and applied initially to the detection of pancreatic cancers in rats (in collaboration with the Photodynamic Technology Department of the Research Institute on Cancers of the Digestive Tract IRCAD, Strasbourg). Figure 1.11 shows images produced during the examination of a rat pancreas. Initial results are very promising and discussions are now taking place to organise limited trials on human patients. A technology transfer initiative, supported by the Innovation Programme of DG XIII (Telecommunications, Information Market and Exploitation of Research) will commence in mid-1999 to produce an industrial prototype diagnostic system for use in clinical trials. In particular, this demonstration system will rely on the integration of the complete fluorescence-imaging device into an existing medical endoscopic system for minimally invasive in vivo diagnostics.

Figure 1.12: Novel medical endoscope developed at ISIS with integrated fibre optic sensors in the tip. The photographs show the fibre cable entering the "grip" and the tip of the 15 cm-long endoscope with the four optical fibres.

The early diagnosis of cancer is often the only hope for cancer sufferers. Until more effective cancer treatments can be found, technologically sophisticated medical diagnostic tools will remain the most important demonstration of advanced technology in the fight against this disease.

Related medical diagnostic tools based on optical technologies are also being developed based on optical fibre sensors. A number of prototype systems have been realised for pressure, temperature and vibration measurement, though a range of measurands is possible. The dimensions of the sensor probes are typically a length of 1 cm by 1 mm in diameter In targeting biomedical sensing applications, a family of miniature sensors have been developed, in particular for in vivo monitoring of critical ill patients (e.g. on-line measurement of intra-ventricular pressure in the brain). Attention has also been given to the integration of miniature fibre optic sensors into the tip of medical endoscopes, as shown in Figure 1.12. This allows clinicians carry out both visual inspection and sensing during diagnosis or treatment.

Fibre optic pressure sensor for medical applications

author: R. Kenny

Fibre optic sensors can offer advantages such as high accuracy, immunity to electro-magnetic noise, high degree of biocompatibility, ease of sterilisation and passive operation. Such properties make optical sensors particularly appropriate for use in medical instruments, for example endoscopes. When combined with ability to operate in hostile environments, these properties also make optical sensors attractive for industry, such as the automobile, aeronautical, plant control, or chemical industries.

Recent work at ISIS, performed with the support of the Innovation Programme of DG XIII, has led to the production of a pre-industrial prototype pressure sensor with the target application being in-vivo pressure measurements. The sensor operates on the principle of amplitude modulation of light, and which is due to deformations transmitted to a modified optical fibre from a membrane subject to external pressure fluctuations. The prototype consists of the sensor head and an opto-electronic unit containing the light source, optical detectors and processing electronics. The prototype sensor head is packaged in a small tube of 1.5 mm diameter, with a pressure sensing silicone membrane covering the distal end. The optical fibre leads of the sensor head may be attached to the demodulation unit using standard FC connectors.

The photograph of the prototype sensor head shows its small size, while the graph of typical response to pressure indicates the sensitivity of the device for the employed silicone membrane. This work has been performed in collaboration with a manufacturer of medical endoscopes and a hospital prepared to perform clinical trials and which has also provided input to the sensor specifications.

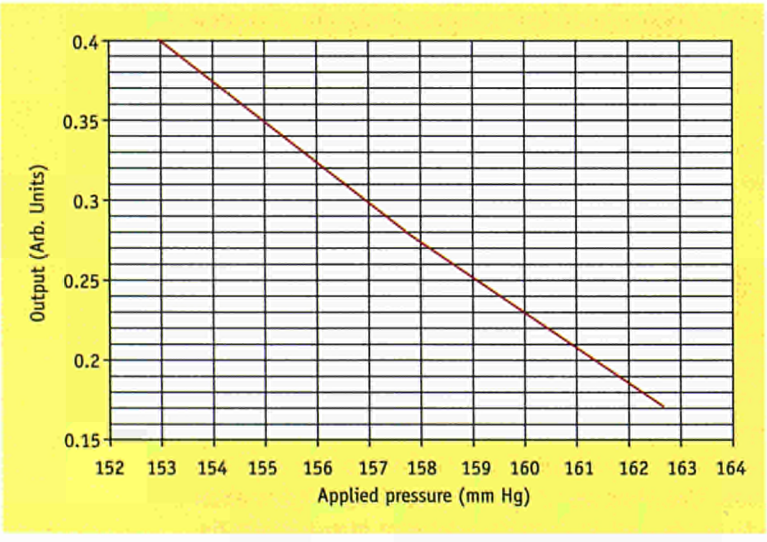


Figure 1.13 Graph of typical response to pressure indicating the sensitivity and linearity of the fibre optic pressure sensors with the silicone membrane.

Three-dimensional reconstruction of real environments

author: J. Gonçalves

There is a wide consensus concerning the importance of three-dimensional interfaces for novel applications such as tele-presence or remote monitoring, or in other words, as a means to provide "the feeling of being there". A current limitation of conventional 3D representations of the real world stems from the gap of quality between the model and the reality "as-built". Traditional virtual models are based on the effort of a human operator drawing manually a virtual object or world, making the entire task time-consuming and inexact. ISIS has much experience in building photo-realistic models of the reality "as-built" and combining these with other sources of data, namely simulated data in augmented reality applications.

To build 3D models from reality, two technologies are combined:

- EST head (Environmental Sensor for Tele-presence): an association of a laser range-finder, TV/digital camera and a scanning system. The 3D structure of the environment is acquired by means of direct, contactless distance measurements with the laser range-finder. The visual appearance is acquired with the camera.

- Mobility: It is almost impossible to create complete 3D models of real environments from measurements obtained from a single capture point, due to occlusions. It is thus necessary to have multiple acquisition sessions by moving the EST head from one capture point to another. To move the acquisition system, three solutions have been implemented:
  - a push-trolley with an on-board computer and batteries;
  - an autonomous motorised mobile platform carrying on board all the required equipment, and
  - a completely manual system based on a tripod and notebook PC.

After each data acquisition session, range data is triangulated and geometric features extracted (e.g., edges and planar surfaces). The models associated to each dataset are first registered and integrated producing a final triangulated model. In the end, each triangle is "painted" with the visual data acquired with the TV/digital camera.
The 3D reconstructed models are encoded in VRML (Virtual Reality Modelling Language) and can be accessed via Internet with a standard WWW browser. Applications areas vary from support to Tele-Presence to real estate or tourism advertising, from modelling nuclear environments to training.
ISIS has been quite successful in the area of 3D, considering the RESOLV and INFOBOY projects as well as the CAMERA research network.

7 *Reconstruction of environments using scanned laser and video (RESOLV)*

ISIS contacts: J. Gonçalves, V. Sequeira

The objectives of RESOLV are to create photo-realistic 3D reconstructed models of in-door environments "as-built", and to carry out application tests on tele-presence, building industry, virtual studios, etc.

Figure 1.14: Two snapshots of a 3D model from a living room. The final 3D model integrates six separate models, each one built from data measured at different locations.

In 1998 RESOLV was extended to 51 months (from the original 26) and IGD Darmstadt (D) joined the consortium. It was fully automated for the reconstruction algorithms: 3D data acquisition, registration, geometric modelling and triangulation, model integration and texture mapping. A social tele-presence trial was carried out inserting a live video into the 3D models. The AEST (Autonomous Environment Sensor for Tele-presence) was integrated with a robotic platform going around a building, acquiring data and incrementally building the 3D reconstructed model of the premises. Moreover, a second AEST was sold to the recently created EdVEC (Edinburgh's Virtual Environment Centre).

8 *Multimedia information kiosk (INFOBOY)*

ISIS contact: J. Gonçalves

With INFOBOY 3D Reconstruction and Virtual Reality techniques are applied to the tourist industry, namely: Internet-based advertisement and information kiosks, as well as CD-ROM catalogue distribution. The trials will concentrate on the advertisement of traditional Bavarian Farmhouses and hotels.

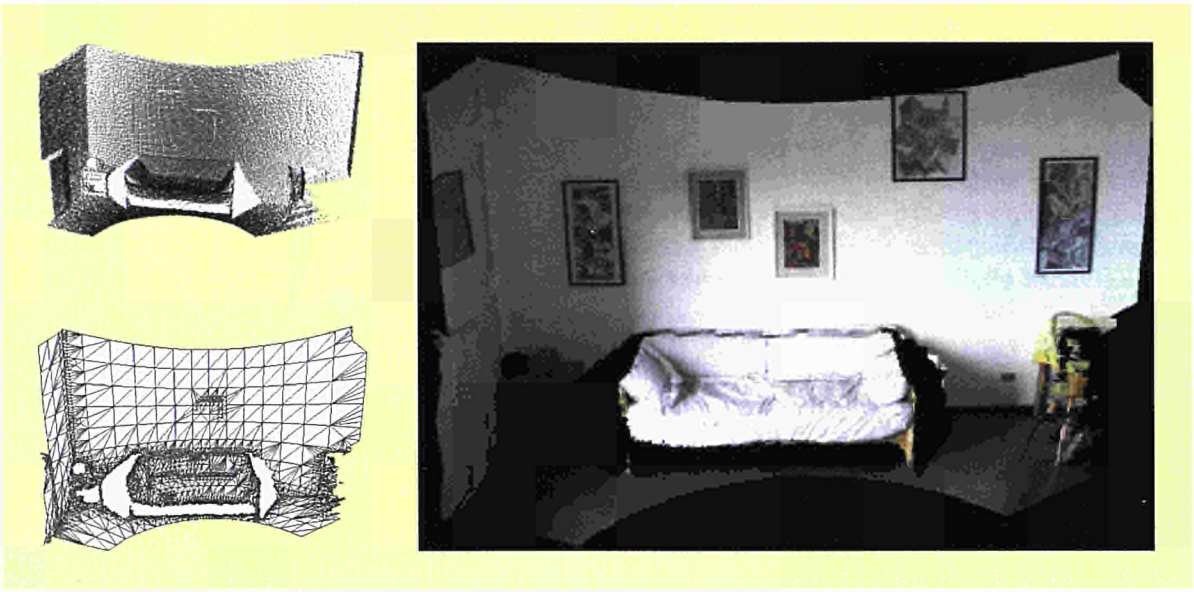


Figure 1.15: The different data processing steps to achieve a 3D model. Occlusions can be observed at the sides of the sofa, i.e., that space was not visible from the specific capture point.

9 CAD Measurements of Environments from Range Analysis (CAMERA)

ISIS contacts: J. Gonçalves, V. Sequeira

The CAMERA research network gathers seven leading European laboratories in the field of 3D reconstruction of environments "as-built". In 1998, the participation of ISIS focused in two main areas:

- *Perception Planning: to determine and optimise the number of capture points for range data acquisition.*
- *Data Fusion: to develop low-level algorithms combining elementary range and visual data to improve the robustness of the geometric modelling of real environments.*

Improving the access of the elderly and disabled to the Information Society

authors: J. Gonçalves, J. Millán, G. Pirelli

The *access* to the Information Society should be done irrespectively of factors, such as, gender, age or previous computer literacy. In particular, the Information Society should count on the *participation* of all citizens and benefit an important sector of the population such as the elderly and disabled (more than 25% of the population in 2020). This requires a major design effort to have efficient interfaces, which are intuitive, easy-to-learn and requiring no technical background whatsoever.

In recent years, ISIS funded a few exploratory research projects aiming at developing alternative human-computer interfaces for the improved access of the elderly and disabled to the Information Society. These internal activities led recently to two European projects: VOICE and Adaptive Brain Interfaces (ABI). The first project addresses the communication problems of deaf people and proposes the use of Voice to Text Conversion technologies in applications such as automated subtitling or telephone for the deaf. The second project explores the use of EEG signals as a way to interface a computer. Two applications are in mind: a communicating media for quadriplegic people and a way of assessing the degree of conscious awareness for humans involved in the operation of safety critical systems.

10 Giving a voice to the deaf by developing awareness on voice-to-text recognition capabilities (VOICE)

ISIS contact: G. Pirelli

VOICE demonstrates how the use of speech recognition systems in conversation, conferences and school lessons, can be translated on-line into PC screen messages. ISIS is developing prototype interfaces for an easier

use of commercial products, taking into account the requirements of people with hearing impairments. It is also investigating the use of this technology in television broadcasts and telephone calls.
The aim is to develop awareness in the field among users, systems producers and services providers, by organising and presenting VOICE at international workshops and congresses [1.22-1.25] and creating a VOICE Forum on the Internet. The prototype has been used to produce life subtitling of part of the VOICE Workshops and User Group Meetings.

11 Adaptive Brain Interfaces (ABI)

ISIS contact: J. Millán

The aim of ABI is to use EEG signals as an alternative means of interaction with computers and recognition of five user generated EEG patterns. The realisation of a compact helmet for the acquisition of high-quality EEG signals, and the implementation of a brain-actuated mouse will be the visible outputs of the project. A spin-off of the project will be technologies

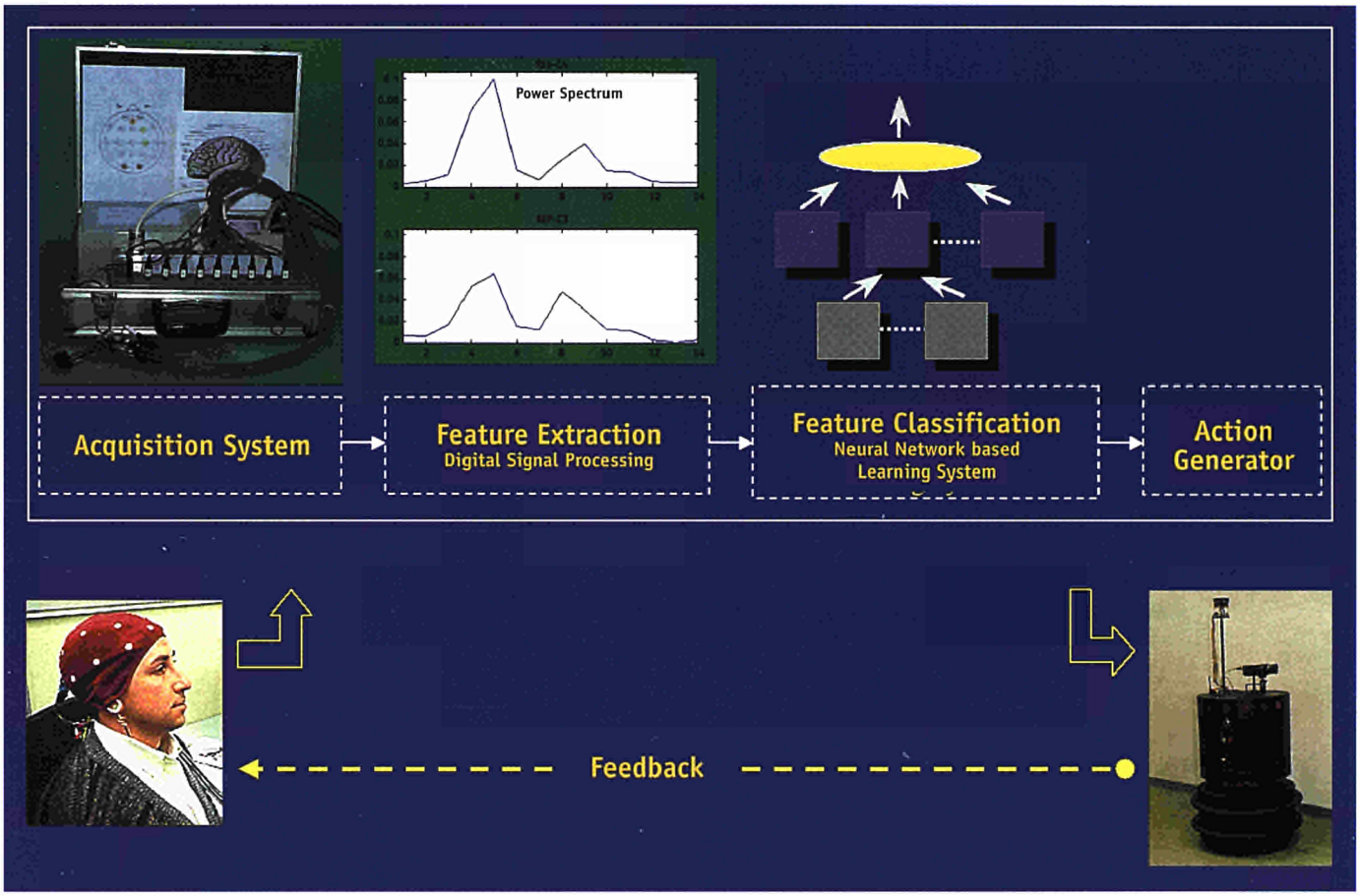


Figure 1.16: System's architecture of an Adaptive Brain Interface. The ABI extracts features from standard EEG signals, and associates actions to patterns characteristic to each individual mental state. By observing the result of an action (e.g., moving a mouse on the screen or a motorised wheelchair) the user learns how to control the system.

[1.22] Pirelli G. The VOICE Project: Giving a VOICE to the Deaf by Developing Awareness of VOICE to Text Recognition Capabilities. In *Proceedings of the Third TIDE Congress Improving the Quality of Life for the European Citizen*, Technology for Inclusive Design and Equality, Helsinki 1998.

[1.23] Pirelli G. The VOICE Project, Part 1: Overview. In *Proceedings of the 15th IFIP/ICCHP International Conference on Computers Helping People with Disability*, Vienna and Budapest, 1998.

[1.24] Paglino A., Pirelli G. The VOICE Project, Part 2: Technical Developments. In *Proceedings of the 15th IFIP/ICCHP International Conference on Computers Helping People with Disability*, Vienna and Budapest, 1998.

[1.25] Pirelli G. Il Progetto VOICE. In *Proceedings on the Web of the HANDImatica Conference and Exhibition for the Integration of People with Disabilities*, Bologna, 1998.

assessing the degree of mental awareness of human operators in safety critical applications.
The project was approved in 1998 and is to run for 36 months from when it started in October. The overall goal is to have each individual user and her/his corresponding ABI behaving as a single entity from the point of view of the outside world as shown in Figure 1.16.

12 Better integration of mentally disabled in industry

ISIS contact: P.C. Cacciabue

As a result of ISIS' know-how in the domain of human error analysis methods, a scientific collaboration between ISIS and Istituto di Ricovero e Cura a Carattere Scientifico (IRCCS) Medea (Italy) was set up to promote a research programme aimed at a better integration of mentally disabled in industry. The intent of this collaboration is to investigate the nature, the characteristics and the typology of common behaviours (in particular errors) of young, mentally disabled people during routine and non-routine tasks. The final objective is to develop training methods and aids fit to enhance the capacity of dealing with risky or undesirable conditions in the working environment. The first step was the development of a human factor classification based on ISIS know-how in accident classification for aviation (see Chapter 6) (including human errors) and the design of a database. While the classification will be used to investigate human-machine interaction mishaps occurring in manufacturing firms, the database will support the analysis and identification of areas to be tackled with new training methods and tools.

Fight against fraud

editor: S. Arsenis

The main activities carried out at ISIS in the fight against fraud covered:

- the development of information infrastructures;
- the estimation of fraud and signals and alarms from relevant databases;
- the electronic identification of farm animals;
- control technologies for fishing.

The primary customer of the first two activities is the European Commission service responsible for the fight against fraud on the budget of the European Union: Unité de Coordination de la Lutte Antrifraude (UCLAF). These activities produce information systems, demonstrate use of available technologies and carry out in-depth analyses from detected cases communicated to the Commission with particular emphasis to the estimation of fraud and extraction of knowledge.

Electronic identification of farm animals is a major feasibility study on applying electronics and database technologies to identify and register farm animals. The study is relevant to both the Common Agricultural Policy and Public Health.

Lastly, two feasibility studies on applications of control technologies for fishing have been launched. These studies aim to determine the feasibility of locating fishing vessels and best techniques for the identification of fish stocks.

New information infrastructures

authors: T. Barbas, R. Steinberger

In 1998, two new information infrastructures projects were completed; the Early Warning Geographical Information System (EWS-GIS) and the IRENE95-Quality Assurance (IRENE95-QA). The EWS-GIS is a geographical information system that visualises transit flow data collected at customs. It uses the database EWS for selected products [2.1]. IRENE95-QA is quality control and quality assurance work related to the in-house, integrated, fraud-case information system (IRENE95) of UCLAF.

The UCLAF Document Management System (UDMS) feasibility study identified areas in UCLAF that would benefit from the application of electronic document management and workflow management technology. This study included a critical view of the user requirements, a technological survey, a practical case study demonstrating solutions for document management requirements using commercial software and a set of recommendations for the UDMS' follow-up [2.2-2.5].

The objective of the UCLAF Data Warehousing project was to analyse the requirements and a general architecture for a data warehousing infrastructure in UCLAF to obtain leverage out of data available to specific sectors. In a case study, a pilot data warehousing facility was developed to consolidate data on textile products (about 150 different categories) and enable further analysis (calculation of market

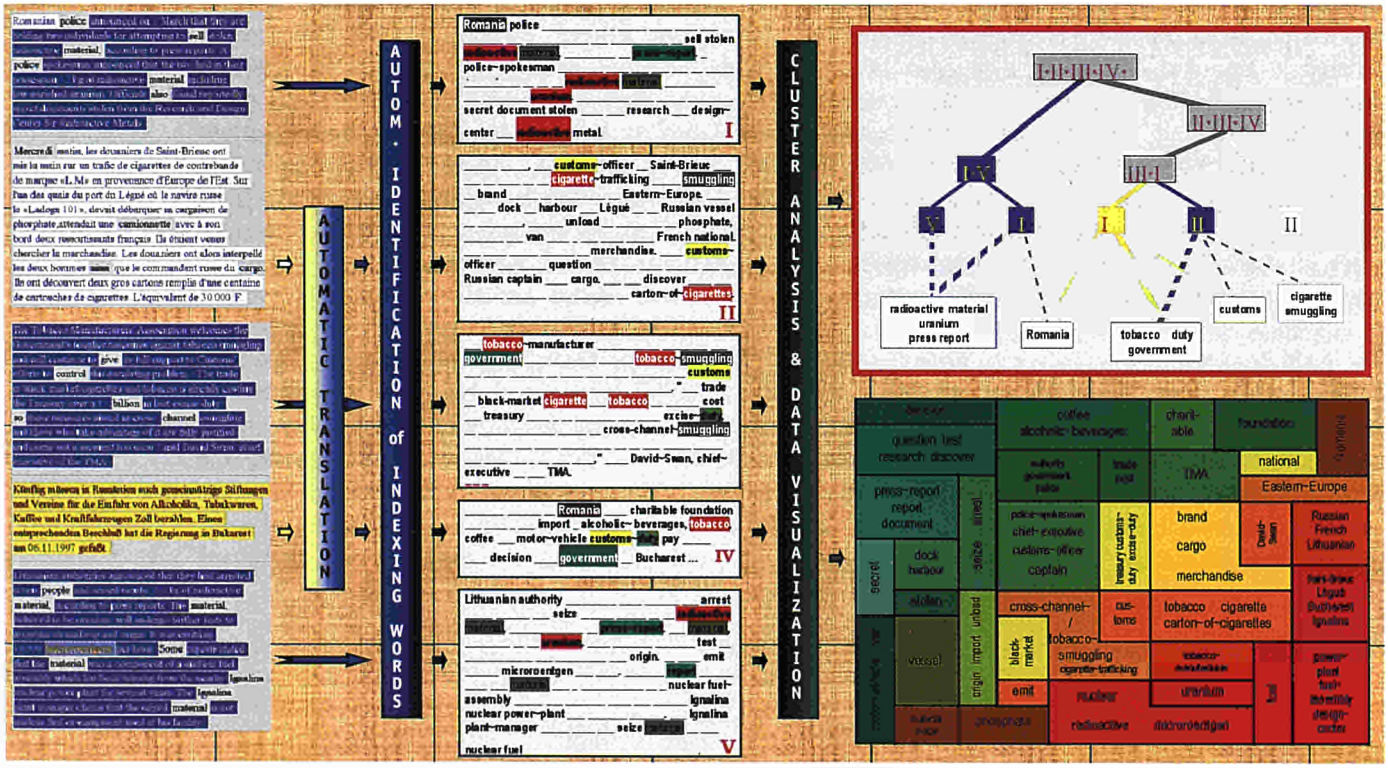


Figure 2.1: Multilingual document retrieval, information extraction and visualisation. To automatically turn the 'information overflow' on the internet and other local or external file systems into a rich knowledge source, it is necessary to retrieve the most relevant documents, to extract the information contained, and then display it in an intuitive manner. The figure shows how the language of retrieved documents is recognised, the texts are translated, indexing words are identified and the information extracted is displayed either according to document similarity or by subject fields.

References

[2.1] Martino S. Early Warning System-Geographical Information System. A GIS Prototype for the transit of Sensitive Products Registered in EWS – (a)User Manual, (b) Project Report. *ISIS/ATIA/133*, 1998.

[2.2] Garg A., Barbas T. Phase 1: Problem Statement for UCLAF Document Management System. *Technical Note I.98.135*, 1998.

[2.3] Garg A., Barbas T., Checchi E. Phase 2: Pre-Analysis for TF-CLAF Document Management System. *Technical Note I.98.212*, 1998.

[2.4] Garg A., Checchi E., Barbas T. Phase 3: Report on Case Study for TF-CLAF Document Management System. *Technical Note I.99.72*, 1999.

[2.5] Garg A., Barbas T., Checchi E. Phase 4: Final Report, UCLAF Document Management System, *Technical Note I.99.73*, 1999.

share, evolution of quantities and values, rankings, warning signs, etc.) [2.6]. Project participants came from several Commission departments representing different points of view, namely, detection of fraud (UCLAF), protection of EU trade (DG XXI- Customs and Indirect Taxation, DG III- Industry) and commercial policy (DG I/D-1- Negotiations management of textile agreements, footwear and other industries). Consolidated data sources were import trade extracted from COMEXT (import trade), preferential import trade reported under the Generalised System of Preference (GSP) and import trade quotas and licenses obtained from SIGL (Integrated System for the Management of Licenses).

The Modus Operandi project started late in 1998. It is part of a series of activities that have the objective of applying Language Engineering – the technology which uses computers to process written text – to support UCLAF staff by automatically analysing and processing large amounts of textual information written in any of the European languages. UCLAF's needs include finding documents relevant to current interests, assessing the contents of documents quickly, extracting the relevant bits of information, presenting them in an informative manner and, possibly, deriving meta-knowledge from texts such as ways in which fraud develops over time and which countries become involved with specific products.

The main goal Modus Operandi is to develop a prototype system which automatically recognises the language in which texts are written, identifies their keywords, detects the subject domains of a text and groups them according to their similarity with each other, the approach can be visually seen in Figure 2.1 [2.7]. The motivation for the grouping is to see whether the clusters of fraud-related texts can be used to derive a fraud case classification. Techniques will be investigated which allow retrieving relevant documents from multilingual document collections such as the internet or UCLAF's intranet. Further activities may include both conceptual and multilingual document indexing, personal information filtering, as well as automatic identification of named entities in texts such as the names of people or organisations.

Estimation of fraud and signals and alarms from relevant databases

author: S. Arsenis

In 1998 ISIS completed a major applied research activity on pattern recognition and risk analysis carried out on data on frauds and irregularities reported to the Commission by Member States. Work developed for this activity is summarised in technical reports [2.8-2.11]. All variables on which data have been reported by Member States have been characterised by a number of suitable developed descriptive statistics. Numerous patterns of positive associations among available variables of interest have been identified to target controls more efficiently as, for example, patterns between products or budgetary lines and types of irregularity, or mis-declared and established origin of products imported in irregularities or frauds against the traditional own resources, see Figure 2.2.

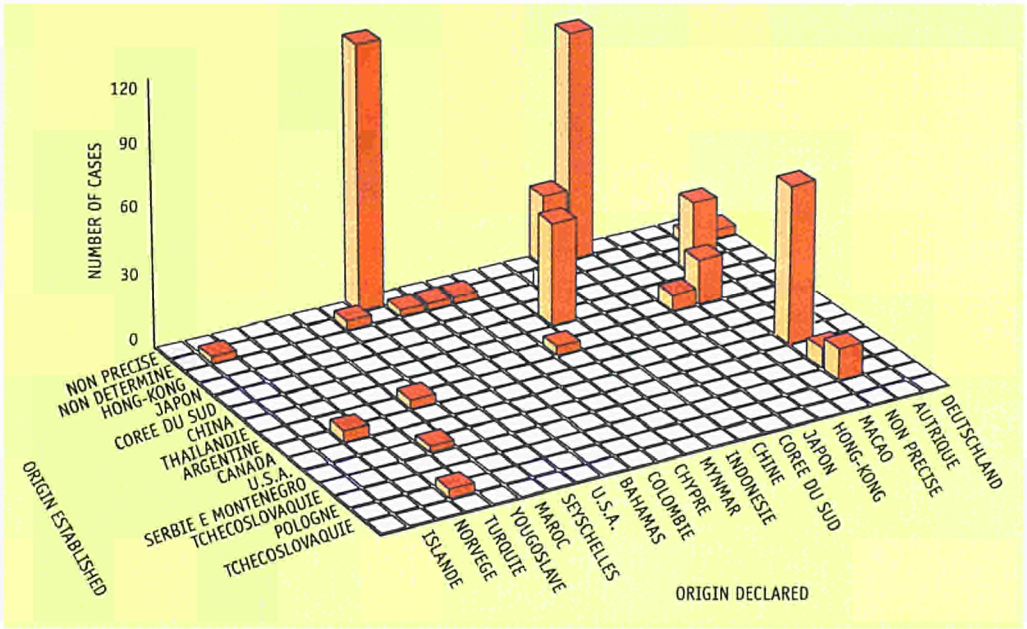


Figure 2.2: Positive associations between mis-declared and established country of origin, reported fraud and irregularities against traditional own resources.

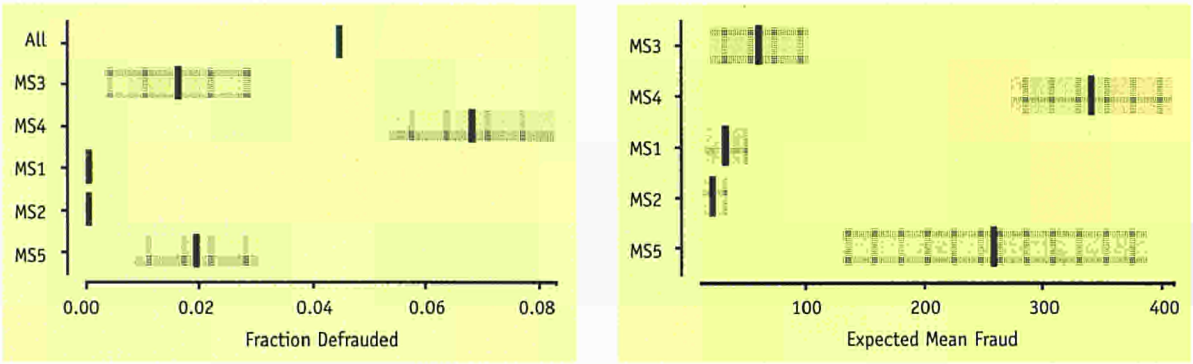


Figure 2.3: 95% confidence intervals for (a) the expected reported budget fraction defrauded and (b) the expected mean fraud reported, by reporting Member States (MS), for a selected budgetary line.

Methodological advances have been made for the estimation of budgetary fractions reportedly defrauded and average fractions defrauded. Such methods enable the identification of Member States which appear to report significantly smaller budget fractions defrauded for selected budgetary lines, see confidence intervals in Figure 2.3(a) and (b); Member States are masked to guarantee the confidentiality of the data.

An optimal stratification criterion has also been developed for statistically sampling for audits. Finally, reference data available with the Commission have been examined to advance applicability of methods to other fraud parameters.
Some of the results here presented have already been taken into account for orienting controls made by Commission services.

Electronic identification of farm animals (IDEA)

authors: C. Korn, A. Poucet

The identification systems currently used in livestock for fraud control and sanitary purposes (eartags, tattoos, etc...) present the inconvenience of losses, breakage, slow data recording and large number of mistakes due to the manual data transcription.

The increase in direct aid to cattle, sheep and goat farmers introduced by the reform of the Common Agricultural Policy (CAP) requires greater efficiency in the management of existing premium schemes. The premium depends on the animal age, species

[2.6] Arsenis S., Atwood C. Pattern Recognition and Risk Analysis for Combating Fraud to the Detriment of the Community. *ISIS/ATIA/109*, 1998.

[2.7] Steinberger, Ralf. Language Engineering Technologies and their use for TF-UCLAF. *Technical note No. I.99.83*, 1999.

[2.8] Arsenis, S., Atwood C. Inference on Fraud from Event Databases as IRENE with Particular Emphasis on Data Requirements. Part 1. Fraud against Budget Expenditures with Applications to LB01-122 and LB01-210. ISIS/ATIA/91, 1998.

[2.9] Arsenis S., Alexandrou V. Statistical Estimation of Total Fraud against Budget Expenditures by Sampling Transactions. *ISIS/ATIA/120*, 1998.

[2.10] Arsenis S., De Amicis F. Descriptive Statistics on IRENE-3 Data with Particular Reference to Variable Typologies, Errors, Multiple Responses and Thesauri. *ISIS/ATIA/156*, 1998.

[2.11] Arsenis S., Kallioras A. On Total and Average Payments and Corrections and the Number of Such Transactions Reported by Member States Based on Aggregated Data of the DGVI Clearance of Accounts. *ISIS/ATIA/159*, 1998.

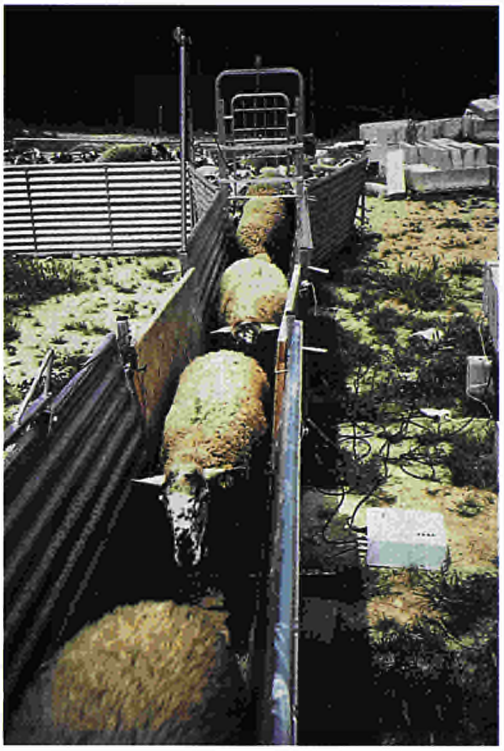


Figure 2.4: For demonstration and testing purposes, 200 animals of a local farm at Ispra (I) have been tagged with boluses and their data recorded in the IDEA (Electronic identification of farm animals) databank.

and breeding type and its assignation is related to the number of animals in each farm. The counting is performed manually allowing the possibility of errors and fraud.
The IDEA Project has been designed to evaluate the feasibility of the electronic identification system in a large number of animals and to validate the system in real field conditions. The project covers a period of three years (1998-2001) and was launched by the DG VI (Agriculture). ISIS gives the technical support in terms of performance testing of electronic identification devices, quality control of equipment, definition and establishment of the central database, data transmission and recording during the project and global evaluation of the results.

One million animals of three species (440.000 cattle, 490.000 sheep and 30.000 goats) in 6 EU Member States (France, Germany, Italy, Netherlands, Portugal and Spain), will be identified applying 3 different types (eartag, ruminal bolus and injectable transponders) of electronic tags, usually named transponders. All transponders and reader types (static and portable) used in the IDEA Project must pass laboratory tests at ISIS's TEMPEST Laboratory and receive the Certificate of Laboratory Acceptance for the IDEA Project. Thus, only certified material can be purchased for the project. During 1998, ten new transponders (bolus, eartag and injectable types) and seventeen new types of readers were certified for use in IDEA. The correct operation of the transponders placed on the animals will be checked periodically (1 day, 1 month, etc...) by reading the electronic identification code programmed on the transponders. All data related to animal identification, control readings and transponder recovery in the field or in slaughterhouses will be recorded at national level and will be sent to a Central Database.

In 1998, the project officially started and the participants proceeded with the organisation of the teams, the acquisition of the tagging and reading equipment and of computer hardware, the training of the staff and the realisation of the local infrastructure. The central IDEA Database was developed and implemented at ISIS. Also, the data transmission software has been developed and is operational.
The analysis and evaluation of the results, will allow to determine if electronic identification is a feasible system to trace animals individually from birth to slaughterhouse, and to identify which technology (in terms of electronic tag and reader types) could be suitable for full scale implementation to all livestock in the EU.

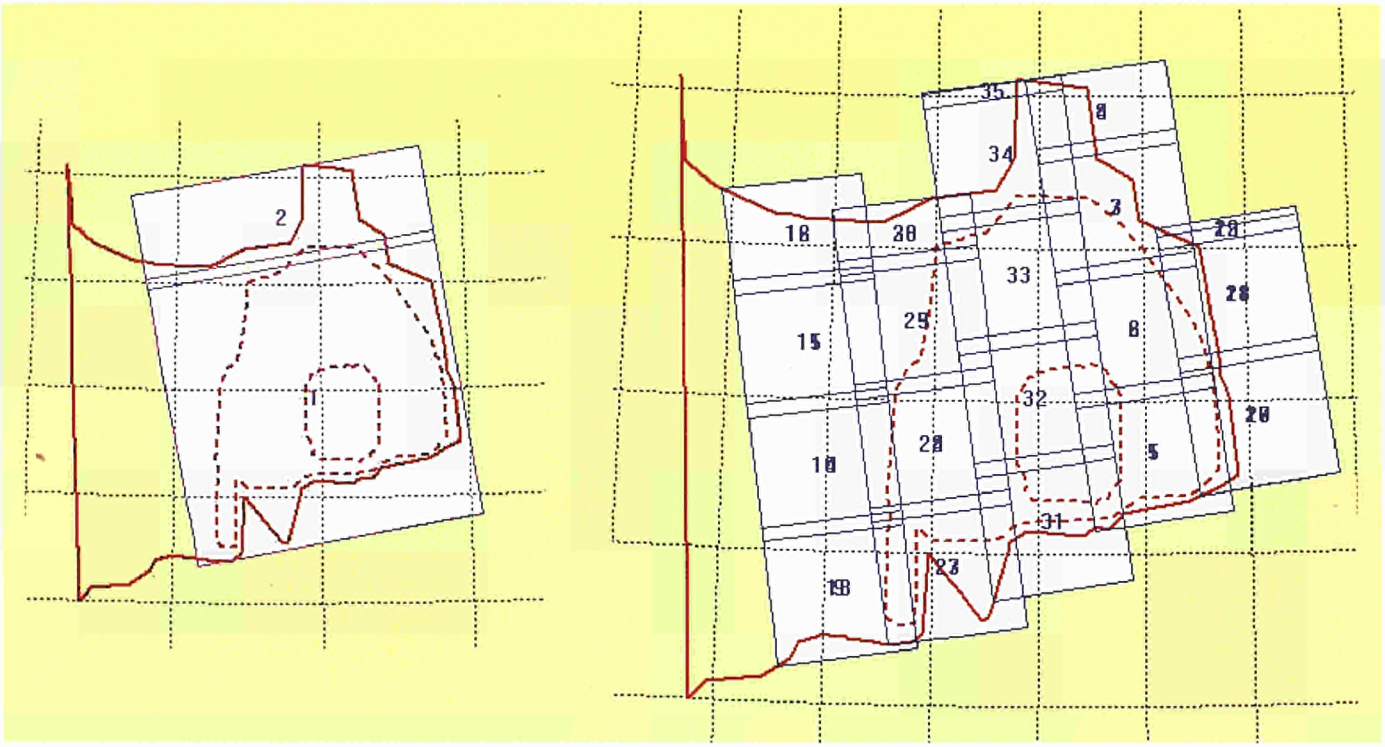


Figure 2.5: RADARSAT coverage of the Flemish Cap fishing area in ScanSar mode with 300 km swaths (left picture) and Standard S7 mode with 100 km swaths (right picture). The inner dotted lines show the Cap itself. The outer dotted line delineates the 1,000 metres' depth area and the outer line is the 2,000 metre depth.

Control technologies for fishing

authors: I. Shepherd, J.-M. Zaldívar

There are various control and inspection mechanisms for the Fisheries Policy either operational or in the process of being set-up. In late 1998, the Fisheries Directorate issued open calls for tender and accepted the proposals submitted by ISIS for following two activities;

- Synthetic Aperture Radar (SAR) imagery for passive detection of fishing vessels;
- development of information technology to facilitate the identification of the origin of fish sold in market through their DNA.

The SAR work will be in collaboration with the Space Applications Institute of the Joint Research Centre (JRC) at Ispra (I) and will concentrate on an area of international water in the Atlantic (see Figure 2.5) where vessels from many nations fish for plaice, halibut and shrimps. The emphasis of the work will be on determining the feasibility of locating those vessels that are not equipped with on-board monitoring equipment using a combination of SAR images and other ancillary information. The aim of the second activity is to study the feasibility of developing an information system, accessible via internet, that can allow molecular biologists to obtain information on known genetic sequences as well as the best techniques to identify particular fish stocks. The work will also include a laboratory demonstration exercise to distinguish between two hake stocks using the molecular biology laboratory of JRC's Environment Institute.

Sustainable development

editor: M. Paruccini

The strengthening of scientific capability is one of the cornerstones of sustainable development. The challenges to science that are posed by the search for sustainability are not only technical ones. There are also fundamental empirical and science methodology challenges for achieving better understanding of our environment and the planet's complex life-support systems. Moreover, there are moral and procedural challenges for defining the roles of science-based knowledge and innovations for governance of technological and environmental risks, for sustainable ecosystem management and for effective communication of scientific information to achieve these goals. In this context, ISIS is actively taking part in this area of basic research.

Another important aspect of the research is oriented towards the engineering of applications such as Decision Support Systems (DSS), which require a tight coupling of advanced multidisciplinary modules, data management systems and interactive, flexible graphical user interfaces. Through a single user device it handles data derived from different areas such as: market analysis, environmental monitoring, traffic flow, land use planning, modelling and data fusion.
The research covers the design and implementation of specific tools for supporting the user in the navigation of the information through predefined cognitive paths and the development of graphical interfaces allowing a non-specialised audience to access complex issues. The research includes the study of information technologies for the integration of advanced systems, such as data base management systems (both numerical and geographic), complex computational models, optimised solving procedures, etc. From these, integrated network architecture is created in which the information systems correspond to the nodes and the links that are represented by gateway procedures able to support communication protocols and data exchange mechanisms. The research covers the study of the new emerging network technologies and advanced developments in the field of distributed information systems - including the evolution of the World Wide Web - distributed computing, multimedia interfaces and tools, etc.

Sustainable development must guide scientific work towards technological innovations that respect fundamental sustainability values such as local ecosystem resiliency, mitigation of global climate change impacts, energy efficiency, food security, and enhanced problem-solving capacities of local populations. An important part of this guidance and justification is the design and implementation of agreed social processes for quality assurance in science knowledge and technological implementations as shown in the projects presented by ISIS in this area. This will entail the emergence of new social institutions to perform the quality assurance function. In this style of science, place-specific knowledge and resources of local communities will need to be integrated as complementary to the universal knowledge of traditional scientific practice.

DECISION SUPPORT FOR SUSTAINABILITY

Decision support

13 Valuation for sustainable environments (VALSE)

ISIS contacts: A. Guimarães Pereira, S. Corral Quintana, S. Funtowicz

The VALSE research project is a demonstration study for social processes and analytical methods for valuation of environmental amenities and natural capitals for conservation and sustainability policy purposes. Valuation and choice have been approached "from the point of view of complexity" - that is, in a multi-dimensional perspective reflecting the variety of scales over which a problem may be considered and the range of individual and collective interests that may be involved.

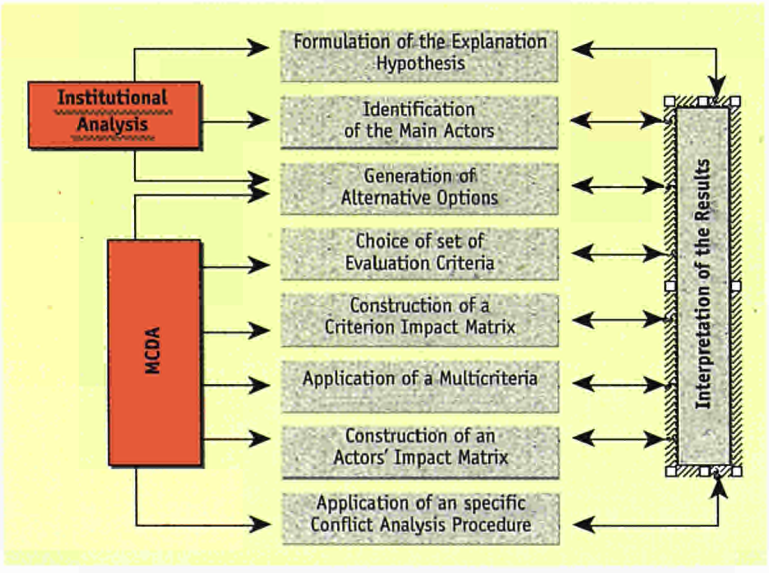


Figure 3.1: Summary of the methodology applied in the Troina project in identifying water resource-use options for regional development using Multi-Criteria Decision Analysis (MCDA).

ISIS actively took part in the Italian VALSE case study. It carried out a multiple criteria decision support analysis to identify water resource use options for the regional development in Troina (Sicily). The water valuation problem for Troina was initially rather vague. There seemed to be a local assumption of a water shortage, which could perhaps be remedied by more effective use of existing resources or by changing access and use priorities. It turned out that, although real water shortage is common in Sicily, Troina is an exception. The situation was clouded by a complex and heterogeneous collection of interests by the stakeholders in the Troina water issue, who up until now have had no effective dialogue. The primary research task was to achieve an effective structuring of the water problem, so that negotiations among stakeholders could have a better chance of a positive outcome.

A multi-criteria analysis was developed on the basis of the identification of the affected interest groups. Criteria and policy alternatives were formulated to take into account the conflicting preferences of these groups. Applying the NAIADE software, a ranking of the policy options was obtained. The multi-criteria evaluation techniques do not solve the conflicts or uncertainties. Rather, they help to provide insight into the nature of conflicts and into ways of exploring policy compromises.

14 Urban lifestyles, sustainability and integrated environmental assessment (ULYSSES)

ISIS contacts: A. Guimarães Pereira, S. Funtowicz

The central theme of ULYSSES is the exploration of the interface between Integrated Assessment Models (IAM) and citizens as part of an Integrated Assessment (IA) approach, focusing on the issues of urban lifestyles and sustainability in the context of climate change.

References

[3.1] Guimarães Pereira A., Gough C., de Marchi B. Computers, Citizens and Climate Change – The Art of Communicating Technical Issues. *International Journal of Environment and Pollution*, 1999.

[3.2] De Marchi B., Funtowicz S., Gough C., Guimarães Pereira A., Rota E. The ULYSSES Voyage: The ULYSSES project at the JRC. *EUR 17760 EN*, 1998.

[3.3] De Marchi B., Gough C., Guimarães Pereira A. Participatory Research and ICT in Venice. In *Proceedings of the Fifth International Conference on Public Communication of Science and Technology (PCST)*, Berlin, September 17-19, 1998. http://www.fn-berlin.de/pcst98.

[3.4] De Marchi B., Funtowicz S., Gough C., Guimarães Pereira A., Rota E. Participatory Research on Risks and the Environment: The Venice Experience. *SPI.98.146*, 1998.

ULYSSES in Venice was realised as a metaphorical journey, which researchers and Venetian citizens made together [3.1-3.4]. Six In-depth groups met five times each using a metaphor of travelling together on a voyage, recording the journey on video and on flip charts posted around the room. A full account of ULYSSES in Venice allows virtual travellers to join the voyage: http://alba.jrc.it/ulysses.html

Two ULYSSES models were used.

- *CO_2 Personal Accounts: This tool, developed at ISIS, compares individual choices for basic lifestyles, such as transport and energy consumption, food, household, etc. to regional and global problems, to create spaces of awareness and discussion about urban lifestyles, sustainability and climate change. This tool was used interactively by participants in the Venice region.*

- *Global Integrated Assessment Models: IMAGE 2.0 (Integrated Model to Assess the Greenhouse Effect) and TARGETS (Tool for Analysing Regional and Global Environmental and health Targets for Sustainability) both developed at RIVM (NL). TARGETS attempts to integrate the study of climate change with other major environment and development problems, incorporating various scientific and cultural perspectives.*

Following their interaction with and discussion around these computer tools (ICT), the Venice participants' evaluation of their usefulness in this context is as follows:

- *Illustration of environmental and social issues, as well as variables' links*
- *Demonstrating different dimensions and perspectives of the problematic*
- *Revealing different scales and propagation effects*
- *Promoting awareness and responsibility*
- *As an information source: learning tools*
- *Providing grounds for personal decisional power*
- *Stimulating discussions and suggestions*

The participants recognised that ICT has value only as part of a broader process and is of limited use in isolation.

15 Integrated visions for a sustainable Europe (VISIONS)

ISIS contacts: A. Guimarães Pereira, S. Funtowicz

The VISIONS project is embedded in the Integrated Assessment framework, involving the use of a number of tools integrated into a dialogue process between experts and non-experts. The main objective is to develop a range of integrated visions for sustainable development for Europe as a whole and for specific regions in Europe, the focus being on key European policy issues.
A number of integrated scenarios for Europe are analysed in the context of participatory processes in three different European regions; Venice is the ISIS study region. The working hypothesis is "Venice as a metaphor of Europe". ISIS is developing (concept and implementation) a number of sustainability scenarios using Venice as a metaphor of visions for sustainability. These visions (scenarios) may be extreme, absurd, creative, different perspectives of what Venice could be by the year 2030. In this way, it should be possible to illustrate how unsustainable our lifestyles are, using Venice as the (representative) example of what is happening and may happen in Europe and globally. Through this exercise one can hope to explore areas of negotiation for sustainability, including contradictions of sustainability with stakeholders in Venice. To introduce social discourses into the process, social research methodologies are used: in-depth interviews and group social research methodologies.
http://alba/jrc.it/visions.html

16 European Forum on Integrated Environmental Assessment (EFIEA)

ISIS contact: S. Funtowicz

The two main objectives of the European Forum on Integrated Environmental Assessment (EFIEA) are:

- *to improve the scientific quality of integrated environmental assessment;*
- *to strengthen the interaction between environmental science and policy.*

The Forum also supports training initiatives on integrated environmental assessment and a collaborative network of scientists, policy-makers and other stakeholders involved in complex environmental issues.

In the first year of EFIEA a wide range of activities were undertaken and eight publications appeared.

After the first meeting, held in March 1998 in Amsterdam, the EFIEA Steering Committee redefined the work plan and allocated tasks to Workshop Organising Committees and small ad hoc groups. Some of these committees and groups have made substantial progress or have finished their tasks, others have just started working.
http://www.vu.nl/ivm/efiea/efiea.htm.

17 Urban transport options for propulsion systems and instruments for their Analysis (UTOPIA)

ISIS contact: D. Bain

The aim of UTOPIA is to provide urban transport decision-makers with the necessary information base, tools and guidelines for hastening the market introduction of the most appropriate transport solutions based on new propulsion systems. It draws together findings from a wide range of disciplines to address the complex issue of how to ensure the successful application of new transport technologies in the market. Ongoing demonstration projects where UTOPIA partners have been involved (ZEUS, CENTAUR) will be used as case studies and test sites. This will allow the tools and methods developed in UTOPIA to be tested and honed during the project. The project analyses the methods and results of new propulsion system demonstration projects around the world. It develops guidelines on the best ways of introducing such systems based on the findings of this analysis. It also develops software to help decision-makers in both comparative testing of different sites where new systems are being introduced, and in finding appropriate technological solutions for specific urban situations. ISIS provides a Decision Support System (DSS) which can be used by city planners in an interactive fashion specific to local conditions. A demo version was completed in December 1998.

18 Management tool for the assessment of driveline technologies and research (MATADOR)

ISIS contacts: D. Bain, C. Böhner

The MATADOR project was part of the EC Joule Programme where the main objective was to bring together the experiences of European test and demonstration fleet. The data of these tests and demonstrations are stored in a database. MATADOR is to make this information accessible for managers and operators of test and demonstration fleet. Furthermore, it is to provide the possibility of comparing the performance of electric and hybrid vehicles with vehicles using other driveline technologies, including the internal combustion engine.
The first part of the project involved extensive interviews with potential users of the proposed management tool. From these it became apparent that there was some reluctance to accept the need for a full-scale Decision Support System (DSS) to assist in choices which are already constrained by a combination of institutional and supply factors. In response to this, ISIS, which had the responsibility within the project for building the anticipated DSS, introduced the somewhat different concept of an "interactive guide" to the various databases and other information sources within MATADOR. A prototype of this MATADOR Interactive Guide (MIG) was developed in the latter part of 1998 and used in the final series of interviews with potential users. The very positive reactions suggest that this innovation, which still incorporates a DSS, meet the demands of the project.

Basilicata

authors: M. Paruccini, R. Wolfer

Within the frame of the EC Structural Funds: Basilicata Project, the University of Basilicata built up a research project called LA.TI.BI. (Laboratorio di Tecnologia Informativa nella Pianificazione dei Bacini Idrografici - a technological laboratory managing water basins). ISIS developed a Decision Support System for the management of a water-supply network on a sub-regional scale. Given the structural elements of the network (dams, locks, connections, etc.) the objective is to support the entrusted authorities in defining effective management policies for the water service. The problem has been modelled by means of Multicriteria analysis techniques, taking into consideration economic, environmental and social issues. A partial hierarchical ordering has been identified among the different objectives, leading to the possibility of designing a multi-stage solution process, where at the top level a combinatorial optimisation problem known as generalised minimum cost network flows has to be solved. This phase is complete and the outcome is a software called AQUAROUTE which will be further developed for the use in other water-related projects. Moreover, since the water is a common resource, part of the project has the purpose of making the knowledge available to anyone who is interested. The main instrument identified for this is the

World Wide Web and a permanent web server is now under construction. This is based on ISIS' expertise on the relevance of an extended process of knowledge sharing and stakeholders negotiation for this kind of public decision-making on strategic issues.

Ministero dell'Università e della Ricerca Scientifica e Tecnologica (MURST)

authors: M. Paruccini, F. Mazzeo

The purpose of this third party work is to focus on and solve environmental conflicts; to design and evaluate the scenarios for decision-making; to identify the best compromise solution as a means for the optimal management of the water body, and to support policy implementation.
During 1998 the MURST project was defined, presented and approved to start in 1999. The project, an agreement between the Italian Ministry and a private company (SNAM Progetti, Italy) is to last 30 months. ISIS, a sub-contractor of SNAM, is to analyse the relation between flooding, water quality, uses of different water resources and social and economic resources.

19 *Scenario-based framework for modelling Transport technology deployment: Energy-Environment Decision Support (STEEDS)*

ISIS contacts: M. Mattarelli, M. Paruccini, D. Bain

The aim of this Shared Cost Action project, which comes within DG XII's JOULE-THERMIE programme, is to build and validate a decision support tool comprising an integrated framework of scenarios and transport-energy-environment modelling techniques. The main purposes of this tool, which will incorporate existing models where appropriate, are to identify which transport technologies are likely to achieve significant market uptake and to quantify the energy and environmental impacts of different technology mixes.
The project began on 1st May 1996 and is being conducted by a consortium drawn from industry, universities and national research laboratories. ISIS has lead responsibility for the central task of software development and validation for the Decision Support System (DSS). In 1998 the main work of setting up the constituent models was substantially finalised and much progress achieved in the task of rendering them compatible with each other and with the proposed DSS. Due to restructuring within the project during 1998, ISIS became responsible for the Vehicle Stock Model.

20 *Integrated Computational Assessment via Remote Observation System (ICAROS)*

ISIS contact: D. Sarigiannis

The purpose of the project, uniting the efforts of 6 institutions (from France, Germany, Greece and Italy), is the assimilation of various data sources (in situ measurements, Earth observation and simulation modelling) to develop links between these three basic data types through an open-ended integrated computational environment. In this way various environmental information sources are integrated into a unique, and optimally managed environmental information processing tool which can be used for air pollution monitoring, extreme incident forecasting and strategic environmental assessment in the urban and non-urban environment.
During 1998, review reports on the state of the art of the techniques and methodologies employed in ICAROS for the integrated assessment of air quality were written by the responsible partner organisations. The JRC, taking into account the state of the art reports mentioned above developed a prototype of the ICAROS platform. Open-ended software architecture was selected using object-oriented information technology (see Figure 3.2). Statistical models correlating the columnar optical thickness of atmospheric aerosol as calculated by the ICAROS algorithms with measured pollutants concentrations have been derived. They will serve as guidelines for the quantitative assessment of the ICAROS implementation in the Brescia and French Guiana pilot projects. A preliminary result of the calculations of pollutant concentrations in the area of Brescia is shown in Figure 3.3.

[3.5] Sarigiannis D.A., Assimakopoulos D., Bonetti A., Huynh F., Lointier M., Schäfer K., Sifakis N.I., Soulakelis N., Tombrou M. ICAROS – Integrated Computational Assessment via Remote Observation System. In *Proceedings in Annual Conference of UK Remote Sensing Society*, Chatham Maritime, Kent, UK, 9-11 September 1998.
http://lcs.jrc.it/icaros.html

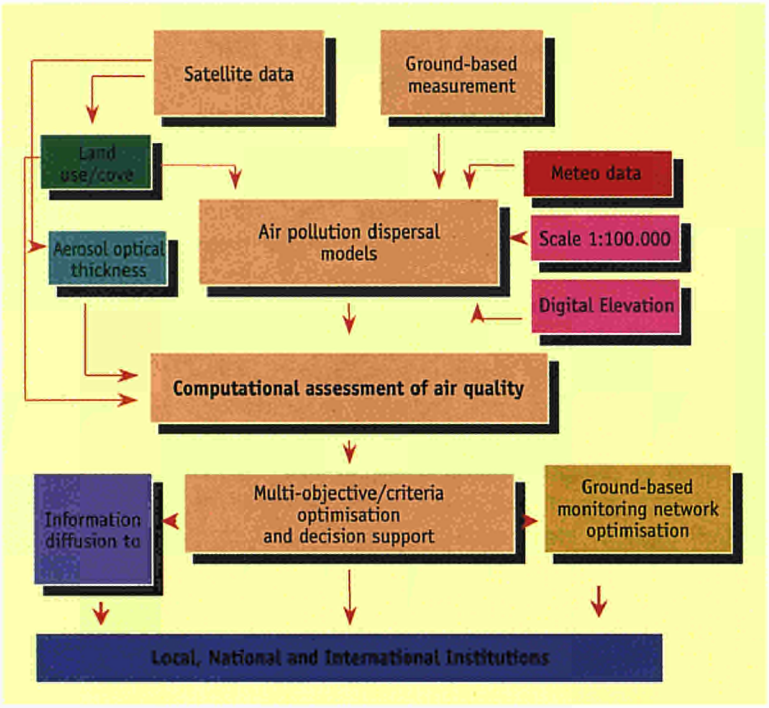


Figure 3.2: Information flow in the ICAROS system.

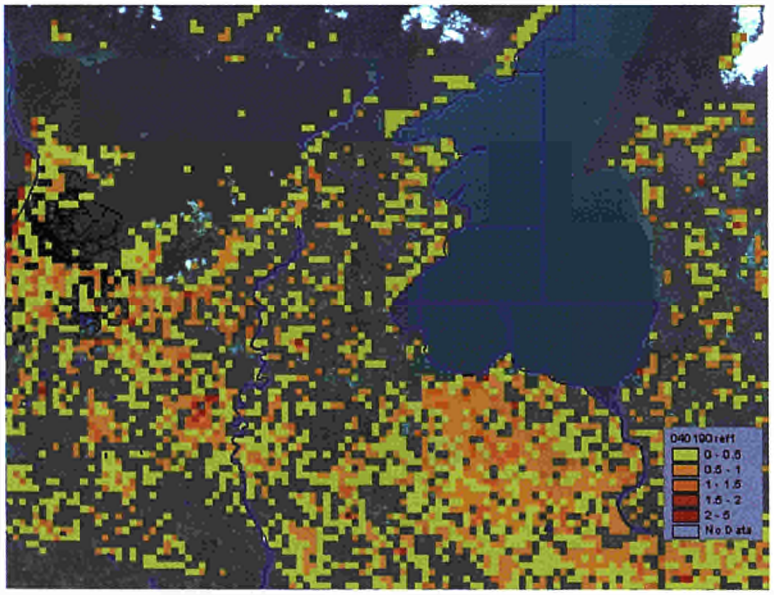


Figure 3.3: Spatial distribution of aerosol optical thickness in the larger area of Brescia (Italy).

Modelling

21 *Long term carbon dioxide and water vapour fluxes of European forests and interactions with the climate system (EUROFLUX)*

ISIS contact: P. Martin

EUROFLUX measures the exchanges of heat, water, and carbon dioxide between forests and the atmosphere above them. Measurements are made in a standard manner and the data is summarised using pre-established methods and stored in a central archive. The EUROFLUX database presents four unique features.

- *For flux databases, EUROFLUX provides a long term (> 1 year) record; previously the time-series averaged about two weeks.*
- *EUROFLUX includes 18 sites using comparable measurement techniques – this is the first case in flux measurement history.*
- *EUROFLUX spans a broad range of latitudes (41°45'N-64°14'N) – by the nature of Europe's geography.*
- *EUROFLUX encompasses very different tree species – something that is hard or impossible to achieve over manageable scales in other parts of the world.*

EUROFLUX also complements this unique database with a set of state-of-the-art models that simulate the exchange of heat, water, and carbon dioxide between forests and the atmosphere above them.

Modelling of carbon dioxide exchange between EU forests and the atmosphere

author: P. Martin

ISIS calculated that, in 1997, European Union (EU) forests could have absorbed between 0.17 to 0.35 Pg (or Gt) of atmospheric carbon. To estimate this range, the calculations used carbon dioxide (CO_2) fluxes as measured by eddy covariance in EUROFLUX (see above) as well as the spatial bio-climatic information compiled by the Forest Information from Remote Sensing (FIRS) project - a map of European forests assembled by the World Conservation Monitoring Centre (WCMC), and by vector data on EU administrative boundaries from EUROSTAT - the

Statistical Office of the European Communities. Combining eddy flux measurements and spatial data constitutes an innovation. By its very nature, the modest "back of the envelope" approach used here strives for simplicity. Nevertheless, it rests on firm physical foundations. Three independent estimates of EU forest CO_2 uptake obtained by forest inventories and by inversion, and using independent data confirm the soundness of the "back of the envelope" estimates. ISIS' estimates imply that EU forests fix between 10% and one third of all EU CO_2 anthropogenic emissions [3.6]. The topic calls for further research. Still, this novel methodology appears promising. Scientifically, it constitutes a significant first step towards much needed "full carbon budgets." In the policy arena, with the Kyoto protocol on climate, information on the exchange and the storage of greenhouse gases (GHGs) gained the status of vital environmental intelligence. In this respect, the present framework makes it possible to regularly update this vital environmental intelligence, to for example, put into perspective the agreement on the burden sharing of GHG emissions reductions reached on 17 June 1998 by EU Environment Ministers, and, more generally, to support policy-making in the post-Kyoto era.

22 *European Terrestrial Ecosystem Modelling Activity (ETEMA)*

ISIS contact: P. Martin

The main objective of ETEMA is to simulate the vegetation response to natural and anthropogenic disturbance, and more precisely modelling of hydrological, physiological, and ecological processes involved in the biospheric dynamics. ETEMA is to produce a generic, comprehensive, process-oriented, modular modelling framework for the coupled dynamics of structure and function in natural and semi-natural ecosystems. ISIS' contribution concerns biosphere dynamics, biogeochemistry, and water and energy exchange modelling [3.7, 3.8].

ETEMA has designed a model "experiment" in which credible alternative model formulations are confronted with critical observational data of different types. Some key data sets for this purpose are being generated by other European projects, such as EUROFLUX and SOMNET, to which ETEMA is linked. ETEMA is also linked to MAGEC, a complementary project dealing with agricultural ecosystems. Efficient implementation of a modular approach in ETEMA has been facilitated by the development of new "generic" model structures for the coupling of "fast" carbon and water fluxes, the coupling of carbon and nitrogen cycles below-ground, and the coupling of vegetation dynamics with biogeochemical processes. A comprehensive model structure will provide a unique tool for the assessment of global change impacts at the landscape to regional scale, including geographically explicit assessments of the consequences of different scenarios of changes in land use, CO_2 and climate. The performance of the model as a whole will be tested against measurable integrative ecosystem "outputs" including NDVI (Normalised Difference Vegetation Index) and runoff.

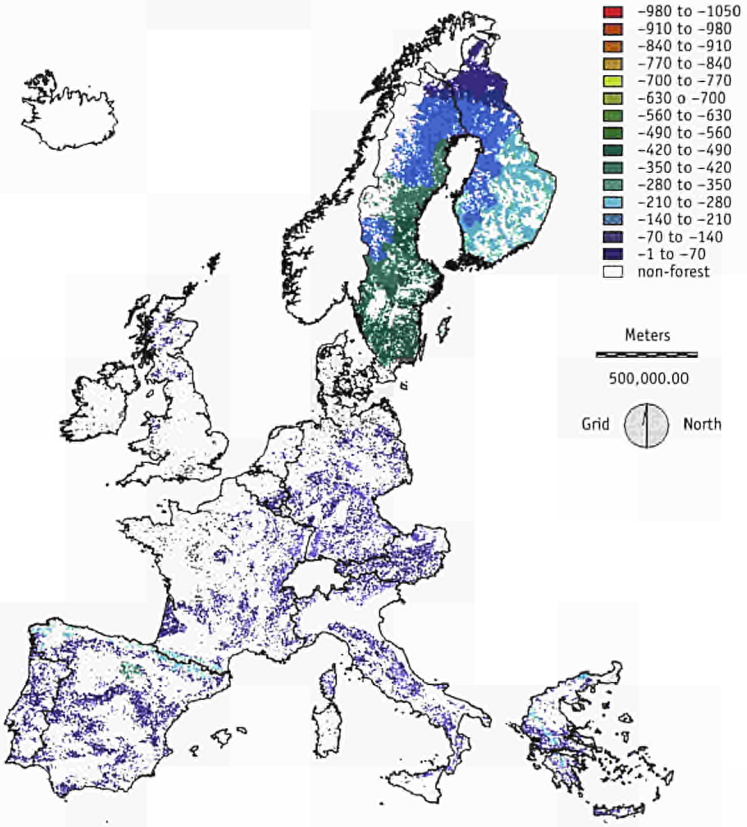


Figure 3.4 (a): Minimum Net Ecosystem Exchange (NEE) between the forests in the 15 European Member States and the atmosphere in g(C) per square metre per year.

[3.6] Martin P.H. et al. A New Estimate of the Carbon Sink Strength of EU Forests Integrating Flux Measurements, Field Surveys, and Space Observations: 0.17-0.35 Gt(C). *AMBIO*, 27 (7), 582–584, 1998.

[3.7] Martin P.H. Land-surface Characterisation in Climate Models: Biome-based Parameter Inference is not Equivalent to Local Direct Estimation. *Journal of Hydrology*, (212-213) 1-4, 287–303, 1998.

[3.8] Martin P.H. Soil Carbon and Climate Perturbations: Using the Analytical Biogeochemical Cycling (ABC) Scheme. *Environmental Science and Policy*, 1, 87–97, 1998.

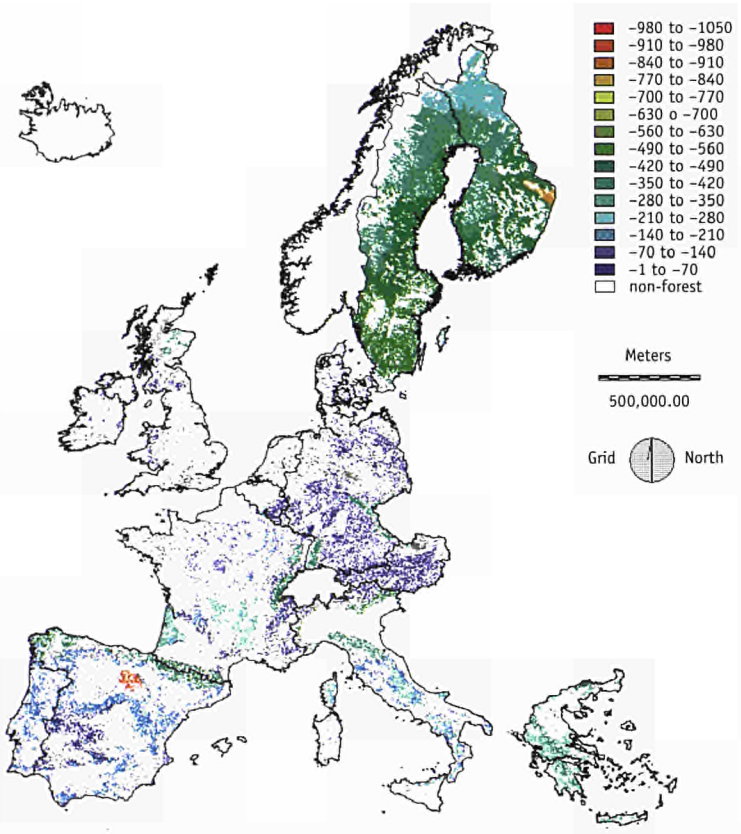


Figure 3.4 (b): Maximum Net Ecosystem Exchange (NEE) between the forests in the 15 European Member States and the atmosphere in g(C) per square metre per year.

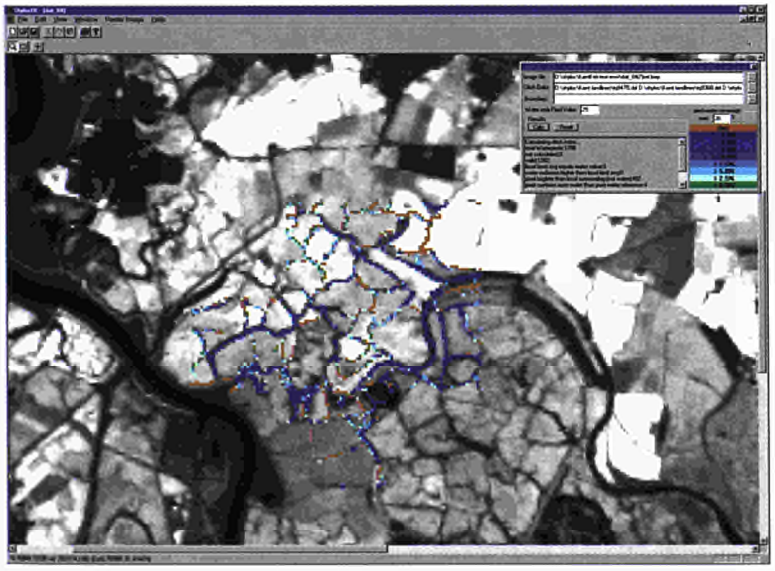


Figure 3.5: The user interface of SHYLOC (inset screen) and colour-coded view of percentage of the stream network that is full of water (main screen). The main screen shows the status of the stream network in the Elmley Marshes, South East England, in February, 1998.

Water resources assessment

author: P. Martin

A concern for water resources management that takes into account the reality of the physical, biological, and chemical world and the different perspectives, educational backgrounds, and interests of stakeholders in water management issues lies at the heart of the VITA (Virtual Integrate Technology Assessment) Exploratory Research. After two years of funding, VITA offers a virtual laboratory to investigate water resources management issues as well as a user-friendly tutorial on how to use this virtual laboratory. The VITA virtual laboratory provides a heuristic software tool that assists both lay people and "experts" in the management of water resources. VITA integrates water biogeochemistry, water quality, and lifestyles. The software includes three modules. One to model water biogeochemistry; on to assess water quality; and one to simulate the effects of lifestyle choices on the environment.

23 System for hydrology using Land observation for model calibration (SHYLOC)

ISIS contacts: I. Shepherd, D. Al-Khudhairy

The main objective of SHYLOC is to develop a pilot system, involving a combination of hydrological modelling and satellite images, that allows environmental impact studies to be made more precisely, enables alternative water management strategies to be quantitatively evaluated, and can determine how best to restore lost wetlands. Overall, the project has been proceeding well. The first year of the project has been characterised by the partners working separately to develop the various components that will be assembled later to produce an integrated effort. These components include the results of questionnaires sent to those responsible for water management in sensitive areas, preliminary versions of hydrological and image processing software and also the installation of measurement stations in the wetland test sites in England and Greece. As well as overall project co-ordination, ISIS have a specific responsibility for the image processing software. A prototype version of the software is now being tested. It is able to read in, display and analyse the combination of Landsat-TM images and ground information required by the algorithms (Figure 3.5). Menu-driven interfaces have been developed that are designed to make the user's job easier.

Decision support for waste-water treatment (ISEO)

authors: I. Shepherd, D. Al-Khudhairy

ISIS is part of a team led by JRC's Environment Institute (EI) working on behalf of the Regione Lombardia to develop the best overall strategy for cleaning up the region's surface waters. ISIS's task was to develop a water quality management model for the Oglio river (Figure 3.6), the largest river flowing into Lake Iseo, the fourth largest Italian pre-alpine lake. The Oglio surface waters are polluted both due to intensive agriculture practices and to inadequate sewage treatment infrastructure. ISIS developed a model of the river and calibrated it with pollution and discharge measurements. In collaboration with the regional authorities a number of scenarios were then developed. These were then tested using the model. The results indicated that it was possible to achieve considerable reductions in pollution input to the lake by constructing or upgrading a limited number of water treatment plants without going to the expense of connecting all households to the sewage system.

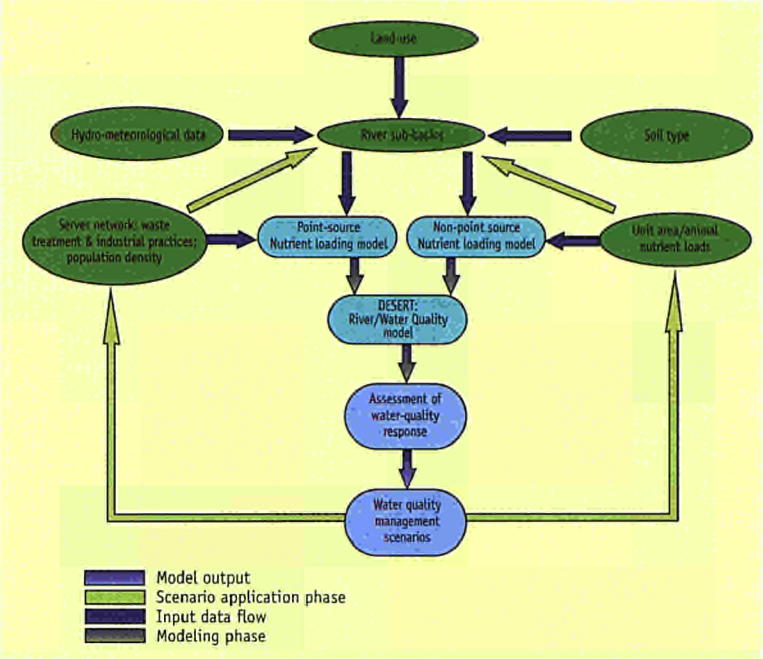


Figure 3.6: A simple framework for the water quality management of the Oglio River basin in Northern Italy.

Fish population studies

author: J. Zaldívar

The central problem of ecology concerns the relationships of individual organisms to their environment, the interactions and diversity of species and the fluxes of energy and materials through ecosystems. Despite tremendous developments during the last decade, there is still a difficulty of connecting models and data. As a background to its increasing effort in support of control measures in fisheries (see Chapter 2: "Fight against fraud") ISIS compared scale deposits from geological sediments from sardines and anchovies off the Namibian coast to the results of a number of calculations with a variety of non-linear models. It was concluded that environmental factors (sea temperature etc.) were responsible for the higher frequency fluctuations - periods shorter than 150 years - whereas density-driven fluctuations due to interspecific interaction competition were responsible for the lower frequencies – periods up to 480 years for sardines and 670 years for anchovies. Because the period examined was before the advent of commercial fishing the study provided valuable insights into the natural variations of fish stocks, helped identify the influence of environmental factors and helped ongoing efforts to develop measures for supporting a sustainable fishing industry.

Urban models

author: D. Sarigiannis

It is increasingly recognised that modern cities are dynamic and self-organising artefacts; they are the result of creative design, architectural implementation, land-use policy and management of human resources within a cohesive framework imposed by their cultural and political history. Modern cities have become multifaceted economic, social, cultural and environmental systems making up an organic assembly of multiple interacting subsystems. Urban and regional development assessment methodologies tend to assume partial equilibrium in economic relations. They hence discard the intrinsic dynamics of the socio-economic system. The latter become all the more evident when approached from the point of view of the interaction of society and economy with the environment. Since 1997 ISIS, in collaboration with the group of Nobel laureate I. Prigogine at the Solvay Institutes for Chemistry and Physics (Belgium) has been developing COMPLEXCITY, an advanced non-linear system model representing the relationship between society, economy, natural

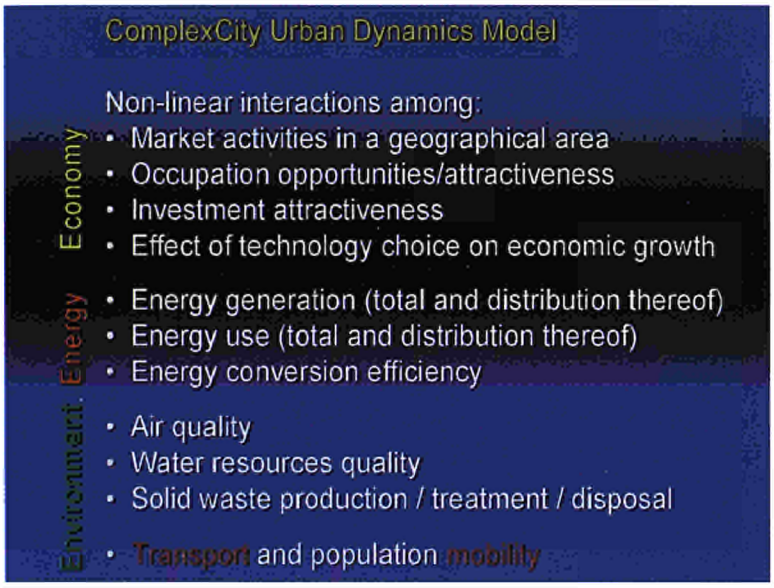


Figure 3.7: Information flow in the ComplexCity urban dynamics model.

environment, energy and transport in an urban complex. Our objective is the development of a tool for analysis and forecasting of the behaviour of the interactive urban sub-systems so as to support urban policy and decision–making.

In 1998, the COMPLEXCITY model was completed and it got validated against historical time series data for two very different European cities: Milan (Italy) and Thessaloniki (Greece). COMPLEXCITY consists of a dynamic spatial-temporal economic model, which incorporates population dynamics and migration patterns. The economic model describes economic interactions at a sector level, although it takes into account differences among various geographical zones in the city. It is coupled with an environmental and a transport model, which describe analytically the pathways through which economic activity affects the urban environment, and vice versa. Technological innovation and the effect of pollution on economic activity and residential preference in the city are treated endogenously in this model. Traffic evolution is treated by network analysis and aggregation of individual behaviours (bottom-up approach) coupled to a macroscopic analysis of road infrastructure carrying capacity. This results in good representation of traffic evolution in both cities where the model was tested, whilst providing indications useful for strategic decision-making regarding urban transport modes. Future work will focus on the use of the COMPLEXCITY tool in support of the City of Tomorrow key action of the Fifth RTD framework programme and of the sustainable regional development policies of the Community. In this context, special emphasis will be given in the northern periphery of the Union and pre-accession countries.

[3.9] Sarigiannis D.A., Guzzi R., Dimou C. ComplexCity. *JRC Technical Note*, vol.1-3, 1999.

[3.10] Sarigiannis D.A. Systems Models for Urban and Regional Development Under Extreme Conditions. In *Proceedings of the First European Cold Conference*, Kiruna, Sweden,11-16 January, 1998.

[3.11] Sarigiannis D.A. Integrated Systems for Urban Air Pollution Assessment. http://lcs.jrc.it/urban.html

Reliability of environmental models

authors: A. Saltelli, F. Campolongo

ISIS has developed global sensitivity analysis methods, applied to environmental issue to assess the quality of models. Sensitivity Analysis (SA) "evaluates" models in several ways:

- By allowing unimportant factors to be fixed or eliminated, thus testing the relevance of models (a model is of poor relevance for a given task if it contains many input factors whose value does not drive variation in the output being sought for the task).
- By falsifying or corroborating a model or by allowing the selection among different models (which model has the preferred sensitivity pattern? Does the given model serve the purpose of –say- an envisaged calibration given the uncertainties...?)
- By allowing a test of the sensitivity pattern against the analyst's understanding of the problem (why is the given factor so important?).

In this context, ISIS has continued its collaboration with JRC's Environment Institute on the use of SA in the construction and corroboration of mechanistic models of chemical reaction systems [1.14-1.16,], while other ecological test models were addressed in [1.9, 1.17]. An original application is in the field of prioritising for the risk from chemicals, in collaboration with the European Chemical Bureau ECB [3.12].

A test case was analysed for EUROSTAT (see Chapter 1, [1.19]). The test case concerns the disposal of solid waste and the choice between two alternative options for waste management: incineration or landfill. The model embodies a chain of uncertainties encompassing data collection, indicator building and decision-making. Through a global SA the output uncertainty can be apportioned to different subgroups of factors. This allows different logical partitions of the factors to be weighed, e.g. controllable and uncontrollable sources of uncertainty, or data, weights and model structures.
The exercise has been carried out for Austria in the year 1994 using data from the Corinair 1994 inventory. Two types of waste were considered: municipal and industrial. Activity rates and emission factors were aggregated to evaluate emissions for all pollutants according to both policies (e.g. incineration and landfill), and emissions were used for indicator building. Alternative choices were allowed for the indicators (the Finnish set encompasses environmental themes such as Greenhouse and Acidification, while the EUROSTAT list includes Air Pollution and Climate Change).
The step 'calculation of indices' is modelled through a weighed sum of the theme indicators. The weights, representative of the seriousness of the problem covered by the themes, include both objective and subjective elements. The objective approach uses targets (for a given year, or for sustainable development), whereas the subjective approach is essentially based on expert judgement.

The model output is defined as the logarithm of the ratio between the pressure index for incineration and that for landfill, using the two sets of indicators.
Uncertainty analysis shows that Finnish indicators promote incineration, whereas landfill is the better option when the EUROSTAT list is used. The main factor affecting the output uncertainty is the choice of the set of indicators. This suggests that the model does not allow a ranking of the two options, as different indicator systems point to different policy options.
The point made by this analysis is clearly not about whether one should use the Finnish or EUROSTAT indicators, but about the relative importance of the various types of uncertainty. This example shows that for this test case subjective criteria (mainly the selection of the set of indicators) essentially drive the decision. This kind of approach is innovative in the context of environmental management because for the first time the problem is tackled accounting for uncertainties that propagate simultaneously through the whole causal chain constituting the model.

[3.12] Sørensen T.M., Saltelli A. Sensitivity Analysis Methodologies and their Applications. *Proceedings of PSAM4: International Conference on Probabilistic Safety Assessment*, A. Mosleh and R.A. Bari (Eds.), 1, 169-174, 1998.

RENEWABLE ENERGY SYSTEM ANALYSIS

24 European Integrated Hydrogen Project (EIHP)

ISIS contact: J.S. Duffield

Europe has gained a leading position with regard to the use of hydrogen technologies and in recent years many hydrogen vehicle and infrastructure activities have been realised. The EIHP consortium, comprising some of the most experienced companies and institutions actively involved in the field of hydrogen vehicle applications, hydrogen infrastructure and hydrogen safety in Europe, have joined their forces with the aim of improving the co-ordination of licensing and approval procedures. ISIS provides support in the definition of safety-related issues by giving a better physical understanding of the release dynamics, dispersion and combustion processes for worst case accident scenarios using the CFD codes ADREA-HF and REACFLOW.

Figure 3.8: BMW 7 series sedan with internal combustion engine drive and LH2 storage, as part of the EIHP: European Integrated Hydrogen Project.

Figure 3.9: View of the AD network visit of anaerobic digestion plants in Bologna (Italy).

25 Anaerobic digestion of agro-industrial waste Information network (AD-NETT)

ISIS contact: D. Sarigiannis

The aim of AD-NETT is to establish a Europe-wide network of expertise to share experience on the anaerobic digestion of agro-industrial waste. Canada, Switzerland and Norway also participate in the experts' network. The technical work includes:

- *Development of a comprehensive database of (a) AD experts and organisations and (b) plant catalogue of projects sites.*
- *Examination of non-technical barriers for technology penetration.*
- *Integrated assessment of local and global impacts and benefits of AD. Environmental and safety aspects have been reviewed and compared with these of traditional farming and waste disposal practices.*
- *Development of a methodology for mapping agro-industrial waste in the EU.*
- *Exchange of information on the performance of successful commercial AD facilities.*
- *Promote best practice in AD of agro-industrial waste through the publication of Summary Reports, Newsletters and Fact Sheets, and the establishment of an AD Web site.*
- *Organisation of a seminar to draw together the findings of the group and publish the proceedings as a definitive source of information on AD for biomass and farm wastes.*
- *Identification of key research and development problems and assist in the direction of future research activities by the EC and Member States.*

In 1998 most of the technical reports regarding various facets of AD system analysis have been produced and the principal means of information diffusion have been set up. The JRC is particularly responsible for the integrated environmental and safety assessment. The relative technical report is currently in print.
http://lcs.jrc.it/energy.html
http://www.ad-nett.org

26 A novel approach for the integration of biomass pyrolytic conversion processes in existing markets of liquid fuels and chemicals (FLASH PYRCON)

ISIS contact: D. Sarigiannis

This project aimed at providing an integrated evaluation of the possibilities to integrate innovative biomass fast pyrolysis and electronic upgrading processes in existent liquid fuel infrastructure. The JRC was responsible for the technical-economic and environmental safety analysis of the overall system. During 1998, technical-economic analysis provided good indications of the unit cost for the conversion of biomass to bio-oil and its environmental burden. Reliability indices of the integrated bio-fuel production plant were rigorously evaluated using probabilistic analysis. The cost and energy efficiency effects of integrating these technologies in an already existing refinery facility were taken into consideration. A computer model for analysis of pyrolysis kinetics to investigate kinetic effects on energy efficiency and plant cost was developed.

The results of the integrated technical-economic analysis, which was the objective of this study, demonstrate the potential of atmospheric fast pyrolysis coupled with electronic upgrading for the production of good quality liquid bio-fuel. Taking into account the results obtained so far by the bench-scale and experimental apparatus of fast pyrolysis (using a circulating fluidised bed) and electronic upgrading reactors the integrated process has demonstrated that in a scaled-up application high reliability of operation can be attained easily. The environmental risk associated with the integrated fuel cycle based on a cradle-to-grave analysis (full life cycle analysis) is much lower than comparable liquid fossil fuel cycles (namely, diesel and other heavy oil products). Energy integration is however recommended for future scaled-up applications. The operational integration of the process into the existing infrastructure of a refinery could provide additional benefits, by (a) ensuring electric power supply, (b) reducing utilities, safety, and maintenance costs, and (c) reducing losses of energy and mass from feed and product distribution.

27 Integrated Spatial Potential Initiative for Renewable energy in Europe (INSPIRE)

ISIS contact: D. Sarigiannis

This project aims to provide a comprehensive methodology for the integrated assessment of the biomass-to-energy potential and in particular of the deployment of Community policy on renewables. This objective poses specific requirements to the methodology employed to integrate economic and environmental analysis. In particular, generic life-cycle analysis (LCA) of the related energy systems and fuel cycles fails to take into account the relative vulnerability of the receptors of the adverse impacts of energy technology. Site and plant-specific environmental impact assessment on the other hand takes into account explicitly the state of health of the local ecosystem and population. However, it is usually costly and hardly ever affects the siting of the plants or the determination of scenarios for policy implementation at the regional level. The meso-scale approach developed in this work attempts to couple the results of detailed generic life-cycle assessment and impact pathway analysis with regional information through the use of state-of-the-art spatial analysis tools.

The JRC meso-scale LCA methodology attempts to integrate: (a) detailed economic evaluation of the total cost of biomass-fuelled energy system (for power and heat production) in non previously existent bio-fuel markets, and (b) life-cycle environmental assessment of the impacts and potential benefits to the ecosystem and human health due to the use of biological resources for energy generation. This tool is addressed to policy makers and energy and financial investors and farmers alike. It aims to assist the integration of renewables into current and future energy markets by providing a comprehensive and well-structured methodology for the evaluation of the feasibility and attractiveness of bio-energy systems to all concerned actors.

The meso-scale LCA was applied in two pilot sites, namely Piedmont (Italy) and Andalusia (Spain). In Piedmont the impacts of meeting the EU goal of meeting 12% of domestic energy consumption by means of renewables and in particular by using Miscanthus, an energy plant for primary energy resource were calculated. A typical result can be seen in Figure 3.10. In Andalusia the potential of solid olive oil waste for energy production was evaluated (Figure 3.11).

[3.13] J. Gretz, D.A. Sarigiannis. State of the art of alternative fuels: hydrogen and biofuels, Proc. Conf. On Energy Technologies and Strategies of Research and Development for the Year 2000, Pisa, Italy, 6-7 March, 1998. http://lcs.jrc.it/energy.html

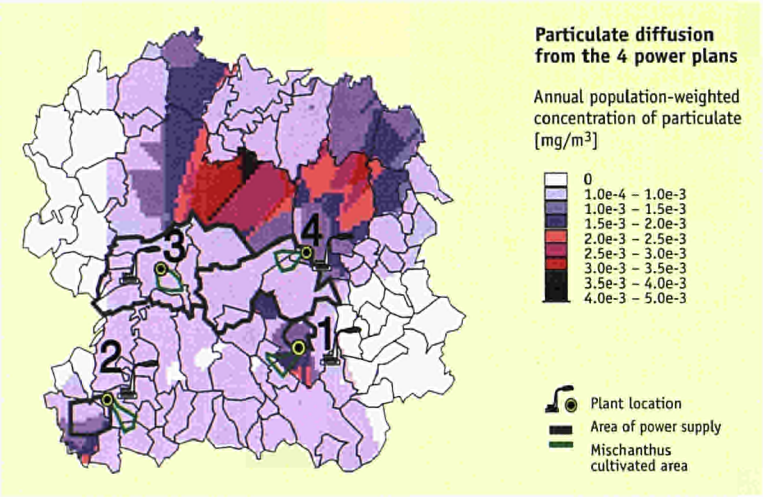


Figure 3.10: Multi-dimensional assessment of the spatial potential for use of Miscanthus for energy generation in the province of Alessandria (Piedmont, Italy).

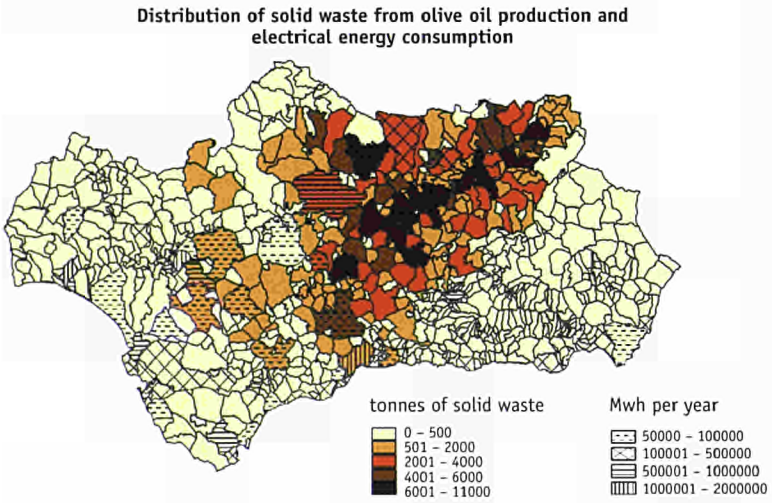


Figure 3.11: Identification of the spatial potential for use of olive oil waste for energy in Andalusia (Spain).

28 Small-scale combined heat and power (CHP) from bio-crude oil fuelled to a stirling engine (BIOSTIR)

ISIS contact: D. Sarigiannis

The major objectives of the JRC contribution to this project are:

- *identification of all costs relevant to the use of biomass for BCO production and finally Combined Heat and Power production in a properly modified Stirling engine;*
- *detailed analysis of the monetary and non-monetary costs and internalisation of these costs to the economic valuation procedure;*
- *life-cycle analysis of the biomass-to-oil and subsequent electricity production cycle with the additional element of valuation using both external cost internalisation and multi-criteria evaluation techniques.*

The incorporation of life-cycle analysis into the design process of BCO production and the extensive use of the technology at industrial scale will allow the identification of the environmentally-sensitive elements of the overall conversion cycle at early design stages. In 1998, the agricultural practices upstream the pyrolysis plant were analysed. First estimates of economic and environmental costs associated with biomass production were produced. Preliminary fault-tree analyses have allowed us to identify critical components of the coupled pyrolysis fluidised bed – Stirling engine system.
http://lcs.jrc.it/energy.html

29 Advanced Mapping of European Biomass Activities (AMOEBA)

ISIS contacts: D. Sarigiannis, F. Ereno

The project will use UK Biomass Programme developments on mapping (GIS - Geographic Information Systems) and statistics collection as a template for an integrated approach and methodology for mapping biomass sites across Europe and the implementation of state-of-the-art information technology in the form of object-oriented databases and distributed information and meta-information systems. Its objectives are to:

- *Develop a European Biomass Atlas for mapping biomass to energy sites.*
- *Provide output in form of maps and statistics as an efficient tool to inform the EC and Member States of the current and projected level of renewable energy contributions (in conjunction with EUROSTAT).*

In 1998, the JRC has collected and geo-referenced all information necessary for the identification of suitable sites for biomass-to-energy investment in Italy and Spain.
http://lcs.jrc.it/energy.html
http://www.etsu.com/AMOEBA

[3.14] S. Dagnall, B. Hillring, D. Sarigiannis. Integrated Spatial Potential Initiative for Renewable Energy in Europe. In *Proceedings of the Ninth EC Conference on Biomass for Energy, Environment, Agriculture and Industry*, Würzburg, Germany, 8-12 June, 1998.

[3.15] S. Dagnall, B. Hillring, D. Sarigiannis. Integrated Spatial Potential Initiative for Renewable Energy in Europe. In *Proceedings of the Fourth EC GIS Workshop*, Budapest, Hungary, 1998. http://lcs.jrc.it/energy.html - http://www.etsu.com/INSPIRE

Risk analysis and emergency management for natural and man-made hazards

editor: A.C. Lucia

The results reported in this chapter, although in large proportion obtained within competitive actions, all belong to the European Community programme line aiming at fighting against major natural and technological hazards. This objective is pursued by the development and improvement of methodologies and techniques for risk analysis and monitoring, information assessment and management, risk forecasting and land use planning, emergency management and alleviation of disaster consequences, improvement of the safety of industrial installations.

Two activity lines were devoted to support the formulation, implementation and monitoring of the relevant Community legislation:

- the Major Accident Hazard Bureau (established in 1996 with the Communication from the Commission to the Council and the European Parliament of 9th February 1996) supports the legislation for the control of major accident hazards, namely Directives 85/501/EEC, 96/82/EC (Seveso I and II) and the upcoming Directive concerning the carriage of dangerous substances in pipeline. The MAHB constitutes also a possible model for the so-called Pre-Accession States, the Central and Eastern European (CEE) States and the Newly Independent States (NIS). To the CEE states was also devoted the Workshop on Land Recovery and Man-made Hazards, held in Vienna in October 1998.
- The establishment of a Community information system on natural disaster is pursued in compliance with the EU Council Resolution of 31st October 1994 on the strengthening of Community co-operation in the field of Civil Protection.

Third-party work projects have been carried out for supporting Regional Policies and actions in the field of Civil Protection. The largest one, funded by the Italian Ministry for the Environment, has been concluded with the final test of an innovative, integrated system for environmental pollution monitoring, accident detection, emergency management and support to land use planning and recovery. The success of the Project led to the conclusion of a new collaboration agreement with the Ministry.

The development of methodologies and software tools for risk analysis, for assessment of RAMS (Reliability, Availability, Maintainability and Safety) and for improving the safety of process industry (with focus on computer models for the chemical industry: run-away reactions, explosions, gas dispersion) has been sidelined by more preliminary or research-oriented activities such as predictability of natural catastrophic events and management of catastrophic risk.

Further activities, relevant to risk and safety themes are reported in other Chapters of this Annual Report; see for example Chapter 6 on Transport safety and Chapter 5 on Safety of civil engineering and cultural heritage structures.

MAN MADE HAZARDS

Major Accident Hazards Bureau

author: J.S. Duffield

The Major Accident Hazards Bureau (MAHB) was officially established in 1996 with the specific remit to give independent scientific and technical support to the Commission to ensure the successful implementation and monitoring of EU policy on the control of major hazards and the prevention and mitigation of major accidents. This most notably concerned the Directives 82/501/EEC, 96/82/EC (Seveso I &II).

The principal customer of the Bureau is DG XI and end users include all the actors in the legislative and regulatory process concerned with process plant safety, (e.g., national and local authorities, industry, research organisations, safety consultants, trade unions).

The Directive and the functioning of the Major Accident Hazards Bureau can also be viewed as a model on which the Pre-Accession States, the Central and Eastern European States (CEE) and the Newly Independent States (NIS) can base their own policies on the control of major hazards and the prevention and mitigation of major accidents.

The transposition of the "Seveso II" Directive into Member States' national law is due to take place by February 1999. This introduces significant changes to policy related to the control of major hazards, and it is these changes and their consequences which were the focus of most of the Bureau's work in 1998.

Under the Seveso Directives, Member States are obliged to notify major accidents to the Commission, and a major effort is made to analyse these accidents and to extract and distribute lessons learnt. To this end, the Bureau operates and maintains an accident reporting system called MARS. Using this system, Member State authorities have a local data logging system, which they use to prepare accident reports. These reports are then submitted in electronic form to the central MARS system run by the MAHB, where advanced analysis tools have been developed to facilitate in-depth analysis of the accidents notified.

The Community Documentation Centre on Industrial Risk now holds over 3000 documents. These include, in addition to documents conventionally published, a wide range of "grey literature", such as company reports, codes of practice, accident reports, safety studies, etc. A CD-ROM was prepared and distributed, holding indexing information, abstracts, and keywords, for all these documents and it is intended that this information is made accessible to the general public through the MAHB web site.

During 1998 a demonstration prototype a European wide, GIS-based, accident analysis package specifically oriented towards "Seveso" industrial plant was developed. This software, the "Seveso Plant Information Retrieval System" (SPIRS), has the goal of containing all relevant data on industrial plant throughout Europe which has to comply with the Directive. It will be made freely available to the National Authorities and various analysis tools can be implemented into the package so that hazard potential and risk categorisation assessments may be performed.

The Bureau, in close collaboration with DG XI, runs a number of Technical Working Groups. In most cases the primary objective of these groups is to develop guidance to ensure a coherent and correct implementation of the Seveso II Directive. During 1998 a full set of "guidance" documents has been completed and will be published prior to transposition into Member States' national law. Guidance documents are available on "Information to the Public", "Inspection Systems", "Safety Reports", "Safety Management Systems", "Major Hazard and Land-use Planning" and "Harmonized Criteria for Limiting the Information in a Safety Report". Further work concerning "Substances Dangerous to the Environment" (TWG7); and "Carcinogenic Substances" (TWG8) is ongoing; with the outcome expected to be in the form on an amendment to the Directive.

Amongst other activities the Bureau also organises international seminars and in 1998 one such seminar was held in Rome on "Inspection Systems and the Examination of the Safety Report". The growing importance of the internet has been recognised and MAHB maintains an active and dedicated web site: http://mahbsrv.jrc.it from which documentation, software tools, MAHB publications and relevant information can be readily downloaded by interested parties. A selected list of MAHB publications for 1998 is given in references 4.1-4.18.

Figure 4.1: The aftermath of the Flixborough accident.

References

[4.1] Kirchsteiger C. (ed.), Christou M., Papadakis G.A. (co-eds.) Risk Assessment and Risk Management in the Context of the Seveso II Directive, *EUR 17676 EN*, Elsevier, Amsterdam, 1998.

[4.2] Mitchison N., Porter S. (Eds.) Guidelines on a Major Accident Prevention Policy and Safety Management System, as required by Council Directive 96/82/EC (SEVESO II), *EUR 18123 EN*,1998.

[4.3] Wettig J., Mitchison N. (Eds.) Explanations and Guidelines for the application of the Dispensation Rule of Article 9, paragraph 6 of Council Directive 96/82/EC on the control of major-accident hazards involving dangerous substances, *EUR 18124 EN*,1998.

[4.4] Kirchsteiger C., Dilara P. Guideline on Reporting Accidents to MARS, *EUR 17734 EN*, 1998.

[4.5] Kirchsteiger C. (ed.) Lessons Learnt from Accidents, *Proceedings of EU Seminar*, Linz, Austria, 16-17 October, 1997, *EUR 17733 EN*, 1998.

[4.6] Mitchison N., Caprioli S. (eds.) Chemical Hazards in Ports and Marshalling Yards/Rischi Chimici in Porti e Scali Ferroviari, *Proceedings of EU Seminar*, Livorno, Italy, 22-24 May 1996, *EUR 17745 EN*, 1998.

[4.7] Amendola A. Viewpoint: Performance measurement in managing for safety - a challenging issue, *International Journal of Quality & Reliability Management*. 15 (1), 1998.

[4.8] Kirchsteiger C. Absolute and Relative Ranking Approaches for Comparing and Communicating Industrial Accidents, *Journal of Hazardous Materials*, March 1998.

Risk monitoring and emergency management

authors: J.P. Nordvik, A.C. Lucia

ISIS continued its activities in support to the Italian Ministry of Environment. It was awarded the management of the technical and scientific support to the two Regional Committees in charge of the Sicilian environmental master restoration plans. The two major projects that started last year, aimed at the design and installation of an integrated system for monitoring and preventing pollution and risks associated with movements of dangerous substances in Sicily, were completed and all equipment were installed on-site for effective use by the various local Administration Authorities. This integrated system explores the possibility to offer at the national level an integrated information exchange network that would cover all the existing Italian risk areas. Feasibility studies for such architecture and implementation in selected Italian risk areas should start at the beginning of next year. The existing Sicilian system was realised through the establishment of monitoring networks and associated control centres over the three major industrial sites of Sicily: Augusta-Priolo, Gela and Milazzo. This activity involved intense co-operation with the Municipal and Provincial Administrations of the three sites, the related Prefectures, the Sicily Region and the Ministry of Environment.

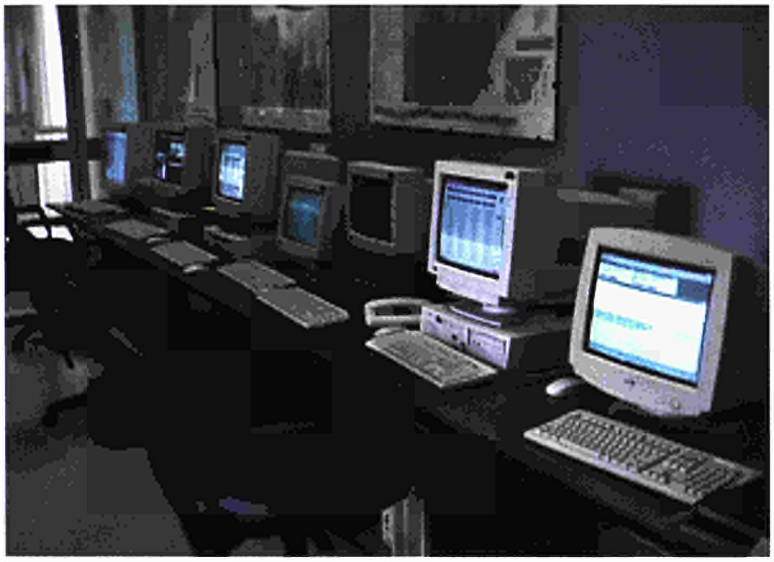


Figure 4.2: Installation in the Prefecture of Messina (Italy) next to the Emergency Room of the Protection Civil Authorities. Hardware installed includes the Provincial air quality monitoring management centre, a GPS fleet management system, a visible and infrared image treatment centre, an emergency management system with real-time gas diffusion modelling, a Meteosat image receiver, and a public information web server.

In each site, a study of the existing industrial risks was performed and a specific monitoring network that complements and integrates already existing environmental networks was set up. These networks include different types of air pollution sensors and gas release detectors as well as conventional and infrared videos. Also, monitoring the movements of dangerous substances in each site is performed with GPS devices and mobile phones connected to a traffic monitoring system.

All monitored data from a site are transmitted to a "Monitoring Centre" capable of distance-managing

[4.9] Kirchsteiger C. Technological and Natural Hazards, Chapter 13 of "*Europe's Environment: the Second Assessment*", European Environment Agency, Elsevier, Oxford,1998.

[4.10] Suarez A., Kirchsteiger C. A Qualitative Model to Evaluate the Risk Potential of Major Hazardous Industrial Plants, *EUR 18128 EN*, 1998.

[4.11] Kirchsteiger C. Risk Assessment and Risk Management as Key Elements to control Major Accident Hazards in the European Union, in *Proceedings of ESA Risk Management Workshop*, Noordwijk, 30 March - 2 April, 1998.

[4.12] Papadakis G.A., Loupasis S. Evaluation of Safety Management Systems and Safety Weighting Policy *9th International Symposium on Loss Prevention and Safety Promotion in the Process Industries*, EFCE, Barcelona, May 1998.

[4.13] Kirchsteiger C. Quantitative Assessment of the Significance of Recurrent Patterns Identified in Accident Descriptions, in *Safety and Reliability*, S. Lydersen, G.K. Hansen & H.A. Sandtorv (eds.) [Proceedings of ESREL '98, Trondheim, Norway, 16-19 June 98], Balkema, Rotterdam 1998.

[4.14] Mitchison N., Clementé C. Safety Management Systems in the Seveso II Directive in *Safety and Reliability*, S. Lydersen, G.K. Hansen & H.A. Sandtorv (eds.) [Proceedings of ESREL '98, Trondheim, Norway, 16-19 June 98], Balkema, Rotterdam 1998.

[4.15] Christou M., Amendola A. How lessons learned from Benchmark Exercises can improve the quality of risk studies, in *Probabilistic Safety Assessment and Management PSAM 4*, A. Mosleh and R.A. Bari (eds.), [Proc. of the PSAM 4 Conference, New York City, USA, Sept. 13-18, 1998], Springer, 1998.

[4.16] Christou M, Porter S. Legislative framework and Guidance procedures for Land-Use Planning in the European Union, in *Probabilistic Safety Assessment and Management PSAM 4*, A. Mosleh and R.A.Bari (eds.), [Proc. of the PSAM 4 Conference, New York City, USA, Sept. 13-18, 1998], Springer, 1998.

[4.17] Kirchsteiger C., Kawka N. Tracing Contributions of Safety Management Systems to Major Accident Occurrences in the European Union, in *Proceedings of the ESReDA Seminar "Accident Databases"*, Antwerpen, 16-17 November, 1998.

[4.18] Kawka N., Kirchsteiger C. User-Driven Knowledge Exploration for the MARS Accident Thesaurus, in *Proceedings of 17th European Conference on Human Decision Making and Manual Control*, Valenciennes, 14-16 December, 1998.

Figure 4.3: Multimedia public information point installed in the atrium of the Milazzo municipality (Italy). Data received from the Provincial air quality monitoring networks are validated, elaborated and disseminated to the general public via Internet, along with general information on national environmental regulations.

Figure 4.4: Video camera installed at Gela (Italy) watches the nearby industrial area. Similar installations with infrared cameras are able to detect "cold" or "hot points", evidences of possible gas release or fire, and to send alarm signals to the Civil Protection Authorities for subsequent interventions.

the network and its various types of sensors, processing and analysing the data downloaded, and communicating the data or other results of analyses to other computer systems.
An "Emergency Management Centre" installed in each Prefecture and fully connected to the related "Monitoring Centre" provides real-time support to the Civil Protection Authorities during industrial and transport emergencies. The Centre stores information on: chemical substances, existing industries and the related accident scenarios, all resources available to the Civil Protection to fight the emergencies, the most vulnerable areas on the territory, and the different procedures and plans used by the Italian Civil Protection. In case of accidental gas release, the use of advanced diffusion models coupled with local on-line meteorological data and 3-D wind field reconstruction provides an estimation of the current characteristics of the diffused cloud and of its future evolution. Results from these simulations are shown directly on maps, along with other thematic layers of geo-referenced information.

The activity also included the installation of five "Remote Interaction Centres" to remotely access the information available from the three "Monitoring Centres" and in case of emergencies, directly cooperate and interact with the main local emergency room. Three "Public Information Centres" inform the citizens on the environmental and industrial risks and on the current local environmental conditions.

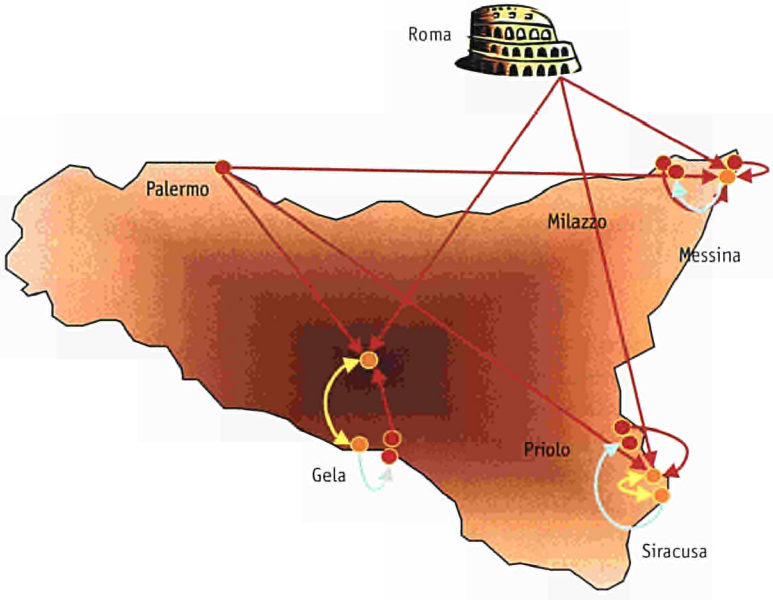


Figure 4.5: Overview of the major network connections installed during the Envireg project (Italy). The ministerial (Rome) and regional (Palermo) headquarters have remote access connections to the Provincial treatment centres of Messina, Caltanissetta and Siracusa (Sicily). In each Province, the Provincial and Prefecture Authorities, along with the Municipality Administrations manage the air quality and industrial alarm monitoring networks.

Figure 4.6: Monitoring station installed on the side of the Gela (Italy) industrial area. Air quality sensors (including a BTX analyzer), meteorological sensors and industrial gas detectors (NH_3 and HF) are installed in a single station. The monitoring network can be reconfigured in real-time to support best the following activities: air pollution monitoring, gas release concentration measurement, local wind-field reconstruction based on real-time wind monitoring. The public and private monitoring networks already in place before the start of the activity have been interconnected for data exchange. Existing stations from the public networks have been exploited to host some of the sensors installed during the project.

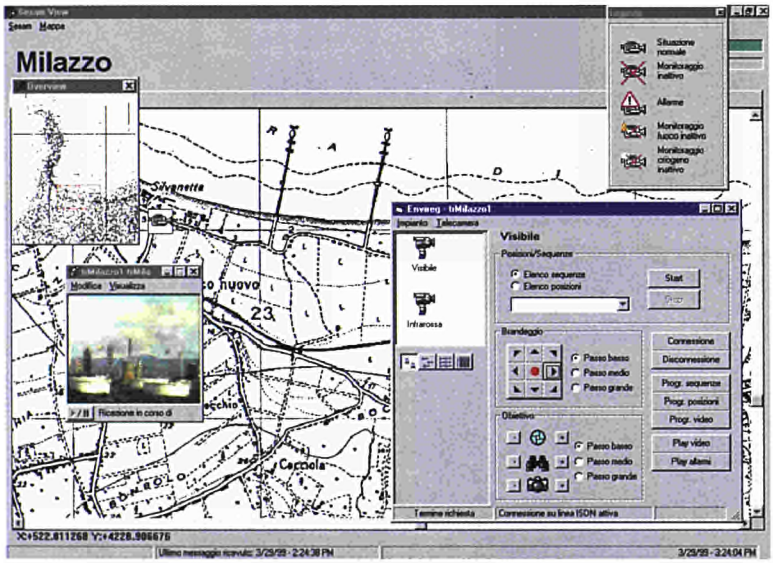


Figure 4.7: Main screen of the video image treatment center. A Civil Protection Authorities can, from its Emergency Room control the various cameras installed over the area and, in case of emergency, watch the current situation over the whole industrial area. Zooming, panning and programmable camera movements allow, under normal circumstances, to automatically record and archive video images of the industrial area, for later vision. Continuous monitoring is ensured by an infra-red camera. Specific algorithms working on infra-red images support automatic detection of "hot-points" and "cold-points", possible evidences of an explosion or of a fire, and of a gas release, respectively. In case of detection, an alarm signal is transmitted to the Emergency Management Centre for further processing.

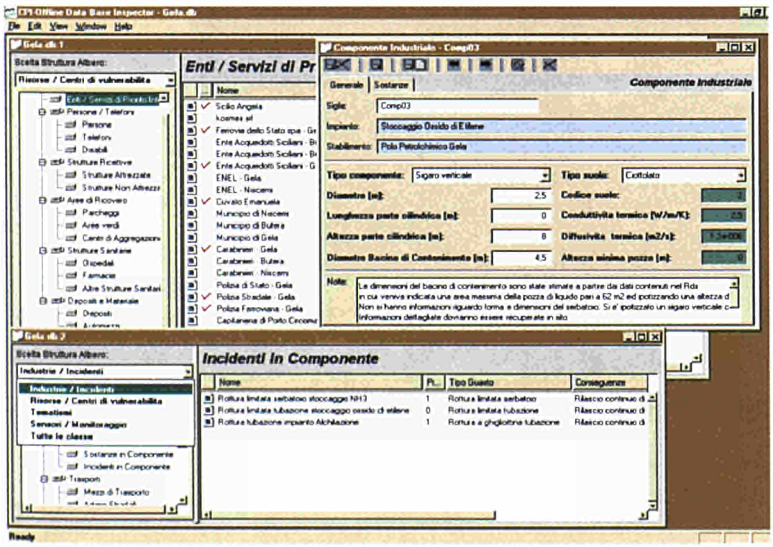


Figure 4.8: Main screen of the database editor of the real-time Emergency Management Centres (EMC) installed in the Civil Authorities Provincial headquarters. All information requested by the EMC, including data on industrial accident scenarios, chemical substances, civil protection resources and procedures, and territorial vulnerability areas, are managed by the editor, including data geo-positioning and vector map edition. During an emergency this information is used to support the management of the crisis, in particular the functions of: identification of the place and type of emergency, assessment of the consequences and definition of impact zones (using analytical consequence modelling or pre-processed procedures recognized by the Italian Authorities), identification of the most vulnerable areas, and execution and tracing of procedures.

Risk analysis and management

A GIS-based software tool for industrial risk management (ARIPAR-GIS)

author: S. Contini

ARIPAR-GIS is a support tool for risk analysis and risk management applicable to areas where potentially dangerous installations are situated close to residential areas. ISIS collaborates with the University of Bologna and the Regione Emilia-Romagna (I) in the development of this software [4.19, 4.20]. Improvements have been made with the financial contributions of the Italian Department of Civil Protection to simplify the input phase and the implementation that is needed for land use planning aspects to respond to the new Seveso II Directive. ARIPAR-GIS, which is currently applied in some area risk studies in Italy, runs on PCs under Windows 95, 98 and NT and makes use of Arc-View 3.0a from ESRI.

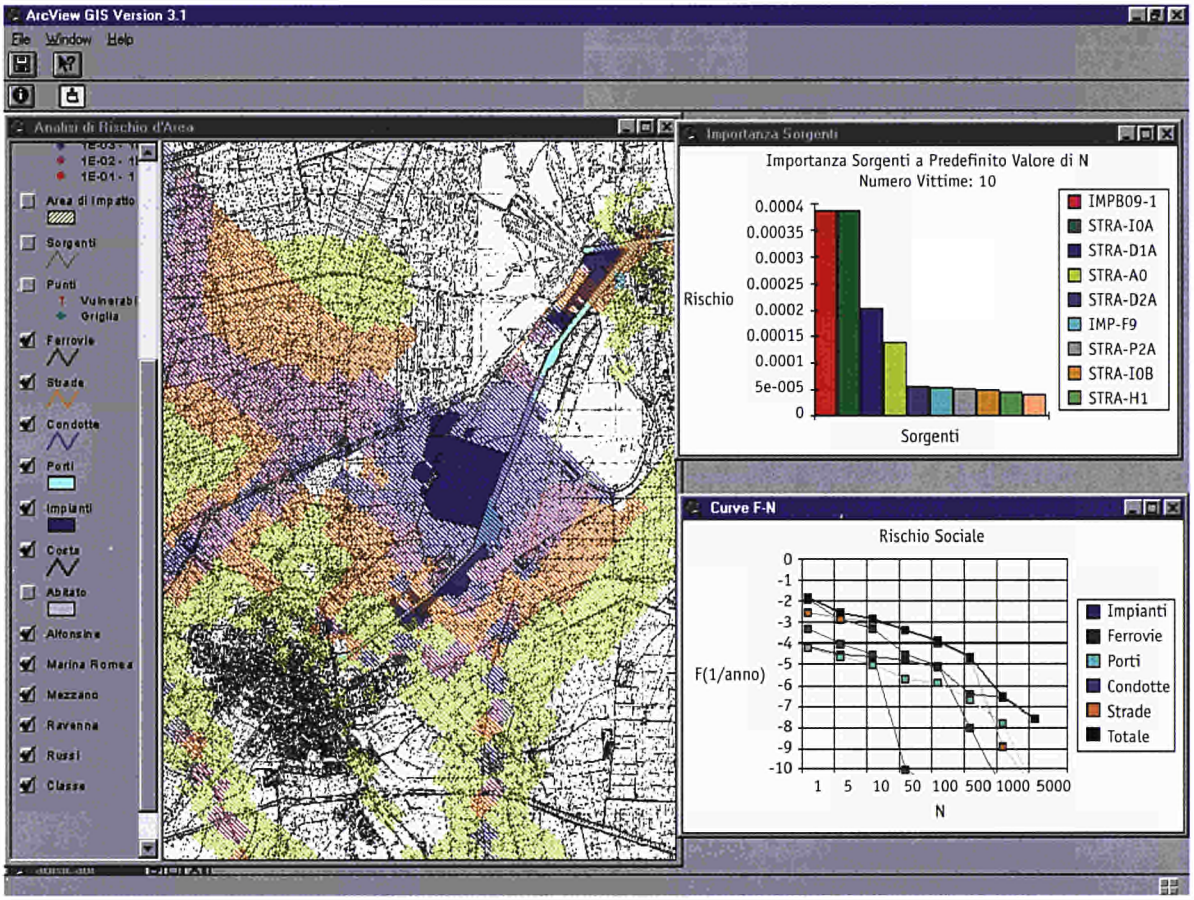


Figure 4.9: Example of a screen-shot of ARIPAR-GIS showing individual risk areas on a geo-referenced map. Points in each coloured area correspond to the probability range of being killed by any accident occurring in industries or during the transport of dangerous substances (purple represents higher risk values).
Also shown are the histogram of relative importance of risk typologies and the Societal F-N risk curves.

[4.19] Bellezza F., Binda M., Contini S., Spadoni G. A GIS Based Software Tool for Risk Management in Industrial Areas. *ESREL 98 Conference*, Trondheim, Norway, 1998.

[4.20] Spadoni G., Contini S., Egidi D. ARIPAR-GIS: un Supporto per le Attività di Previsione e Prevenzione dei Rischi e la Preparazione all'Emergenza in Aree Industriali e Portuali a Rischio di Incidente Rilevante Convegno Nazionale su Valutazione e Gestione del Rischio negli Insediamenti Civili e Industriali, Pisa, Italy, 1998.

Risk management for the Lombardy Region (GIRL)

author: S. Contini

In the frame of a contract with IReR - the Research Institute of the Lombardy Region, Italy - ISIS has developed a support tool for risk management. It is based on Arc-View 3.0a and consists of a suite of programmes to manage the information related to the risk posed by storage and process installations. The tool is made up of a set of databases on relevant plants' information, a module to calculate the impact of possible accidents and a simplified statistical module.
Characteristic data on a significant number of plants have been loaded into the databases. They concern e.g. the geographic location, the process/storage description, results from the analysis of the safety report, effects of accidents, and so on. Raster maps of the region (scale 1:10.000) and a number of thematic maps are being used to display the distribution of industrial installations in the Region and the impact areas of accidents.

30 ASSessment of the Uncertainties in Risk ANalysis of Chemical Establishments (ASSURANCE)

ISIS contact: A. Amendola

Objective is the evaluation of the state-of-art of risk assessment, models and techniques in use, and associated uncertainties. This is achieved by investigating results and problems identified via an independent analysis of a reference subject (storage of Ammonia and related transport interface activities) performed by different teams.
ISIS shares the scientific co-ordination and the analysis of the results with RISØ.

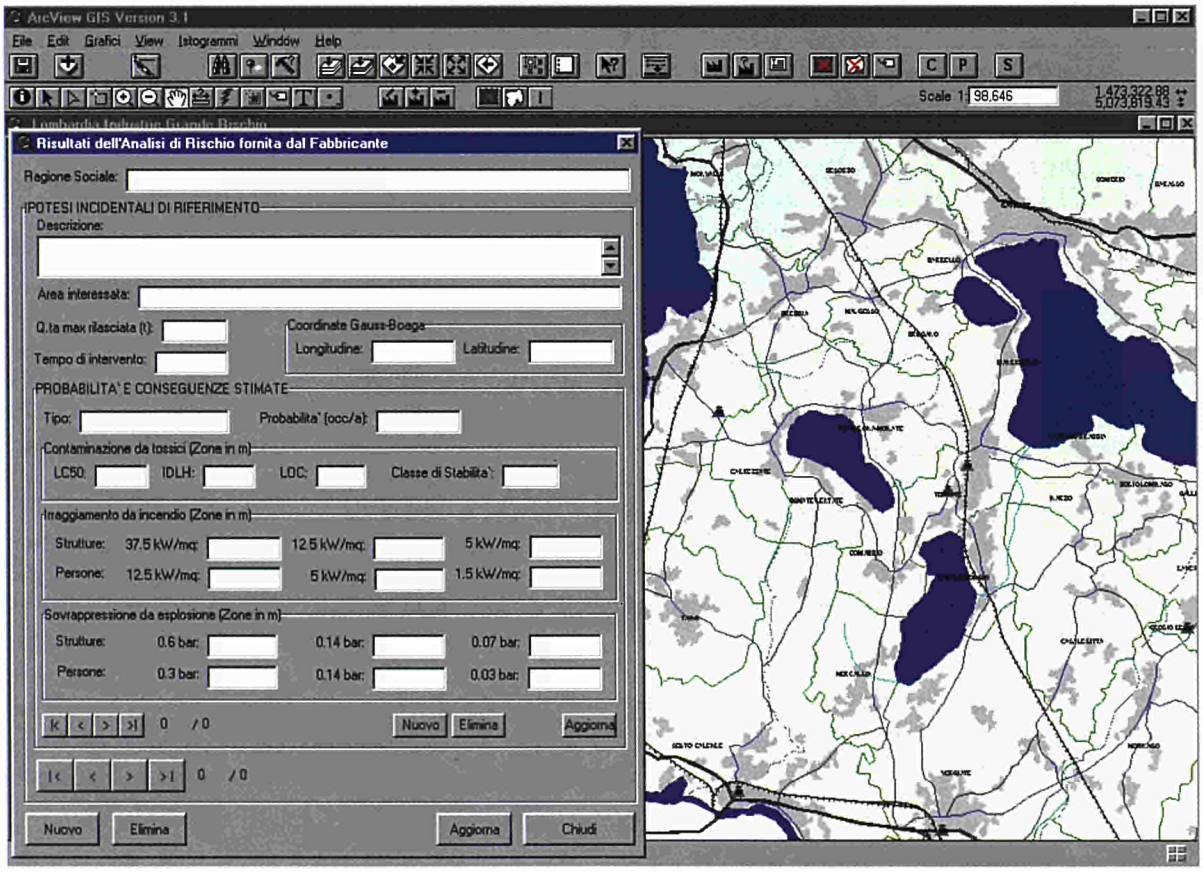


Figure 4.10: Example of a screen-shot of GIRL showing part of the Lombardy Region and one of the forms for collecting data on accident consequences.

[4.21] Bellezza F., Contini S., Guagnini G. Sviluppo di Criteri per la Classificazione dei Rapporti di Sicurezza. JRC *Technical Note I.98.140*, 1998.

The project has been originated by previous ISIS organisations of benchmark exercises on risk and reliability assessment of complex systems, which proved valuable for the development of sound risk assessment procedures. The results will be particularly relevant for the support given to the EC policy on the Control of Major Accident Hazards.
The project started in 1999 with the collection of the documentation needed from the reference plant.

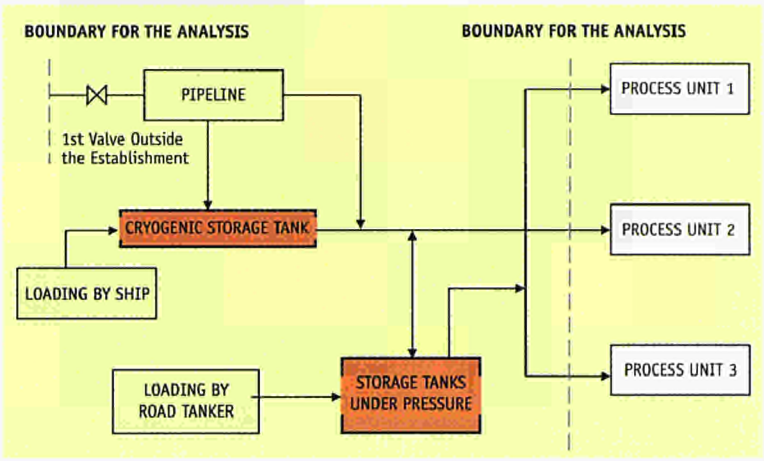


Figure 4.11: Assessment of the uncertainties in risk analysis of chemical (ASSURANCE) reference plant activity.

Land recovery and land use planning

Land recovery and man-made risks

authors: J.S. Duffield, A.C. Lucia, N. Mitchison

ISIS held an international workshop in Vienna 16th-18th November 1998, in co-operation with Austrian research centres, focusing on the problems and needs of the pre-accession countries in the domain of land recovery and man-made risks, a domain in which ISIS has considerable expertise. The workshop was by invitation only and high level experts from the pre-accession countries met together with the major, European, technological and policy making players in the field of land recovery and man-made risks. The following conclusions and recommendations were drawn from the meeting:

- Land recovery is considered a critical problem in all the pre-accession countries, arising from its consequences on water resources and use of the land, with many of the specific problems being common to all countries.

- There is no completely common legislation for dealing with land recovery, this is true for the EU member states as well as the pre-accession countries. There are however, directives and proposed directives that are relevant to land recovery and man-made risks; these concern waste management, water quality and industrial pollution control and risk management. However, key issues have been identified for the problem of land recovery i.e., the need for different approaches for dealing with past contamination and new contamination, and the need for defining an "acceptable" level of clean-up being dependant on the proposed land usage.

- There is a need for research and development focusing on methodologies for assessing the consequences of different policies and strategies, including different economic and legal instruments.

- Compatible national central information systems must be established covering the collection, assessment, up-dating and management of information and effective communication among interested parties.

- There is a need for transnational mechanisms and systems for exchange of knowledge, methodologies, expertise, best practices and for training.

- In dealing with the man-made hazards of land contamination the aims of each country should be: to reduce the risks to a level consistent with the economic, social and environmental needs, and to bring land affected by contamination back into beneficial use.

- While the priority is to implement the existing specific directives for waste management, water quality and industrial pollution control and risk management, each country should consider what other measures may be necessary to deal with the problems of past contamination to ensure the necessary infrastructure for environmentally friendly development and to set clear conditions for investment.

Based on the general conclusions stated above the following key recommendations have been put forward as the outcome from the different working groups.

- Criteria which should include an assessment of risk should be central in the decision making process connected to land recovery problems to

ensure maximum efficiency in the use of resources. Screening or tiered approaches should be adopted and benchmarking of qualitative methods for risk assessment is suggested.

- An inventory of available techniques used in land recovery should be created along with selection and validation criteria.

- The following priority R&D actions have been identified:
  - Development of screening techniques for the detection of pollution to improve the targeting of resources.
  - Development of more cost effective soil remediation techniques with priority being placed first on natural attenuation, then enhanced attenuation, barrier methods, in situ methods, ex situ on site methods and finally as a last resort to off-site intrusive techniques.

- Priority should be given to monitoring "before" and "after" remediation and this should be coupled to predictive process modelling in support to decision-making processes. There is a particular need for the development of low cost monitoring equipment, strategies and methodologies and the development of criteria to deal with the problems of sites containing multiple types of contaminants.

- The research and development needs of the pre-accession countries should be integrated into existing international networks dealing with the problems of land recovery and man-made risks such as: CLARINET, NICOLE NATO/CCMS and ETC/S.

- The execution of joint projects focusing on real problems are seen as the most effective and efficient means by which knowledge and expertise is exchanged between the EU member states and the pre-accession countries, and finally exchanges of scientific personnel and the hosting of international workshops should be actively encouraged.

31 *Land use planning and chemical sites (LUPACS)*

ISIS contacts: M. Christou, J.P. Nordvik

LUPACS deals with land use planning problems linked to the siting of chemical industrial complexes. The objective of the project is the development of a methodology for land use planning where chemical sites and related activities are involved. The methodology supports the risk overview, validation of siting choice and evaluation of consequences for land use. The land use planning process is investigated through three case studies concerning a refinery, a steel production plant and a chemical plant. In the framework of the project, the contribution of the ISIS is mainly concentrated in the definition of the skeleton of the methodology with focus on the application of MultiCriteria Decision-Making Analysis in the context of land use planning problems associated to the expansion of high-level risk plants. In the land use planning problems analysed in the project, the alternatives are identified by the combination of predefined land development types for each of the critical areas (exposed to a high risk level) of the region around the chemical facility. The evaluation criteria considered and quantified are economical and risk criteria. In LUPACS, the Reference Point approach has been applied and validated as MultiCriteria Analysis methodology. It is based on the conceptual and mathematical model of the decision-maker's levels of aspiration. It is an interactive model, in which the decision-maker can progressively identify different preferences until he manages to obtain a solution that he considers satisfactory. The ranking of the alternatives is induced on the basis of the conceptual of distance from a reference point in the decisional space. The method has been applied to the outcomes of a pre-processing phase in which all the efficient alternatives are generated and evaluated with respect to the criteria chosen for the integrated assessment. The methodology allows the decision-maker to model his preferences and to obtain a ranking of the alternatives accordingly. The method was well suited to the problem tackled and well integrated with the pre-processing methodology for the generation of the alternative land use patterns.

Software for reliability, availability, maintenance and safety (RAMS)

ASTRA toolset

author: S. Contini

The aim of the ASTRA tool set (Advanced Software Tool for Reliability Analysis) is to offer the user various tools for complex systems dependability analysis. The current commercial version of ASTRA, running on personal computers under Windows 95, 98

and NT operating systems, comprises the following modules:

- ASTRA-FTA: Fault tree analysis
- ASTRA-PTD: Time dependent probabilistic analysis
- ASTRA-SAM: Interactive sensitivity analysis:
  The latest module developed, ASTRA-SAM, offers the analyst the possibility to improve a complex systems' design from the safety/availability viewpoints. This is based on the sensitivity analysis technique (SA) applied to the results of fault tree analysis.
  Each fault tree is assigned a user-defined probabilistic goal, to be satisfied during the design improvement process (see Figure 4.12).
  The main characteristic of ASTRA-SAM is that SA is performed on all system fault trees concurrently, and as such the user is able to carry out trade-off analysis. A decision tree represents adopted system modifications. The effects of each modification on all system top-events are immediately displayed. Besides the modification of events' parameters, the user can apply various types of redundant configurations (parallel, K-out-of-N, Stand-by) or modify the trees structure.

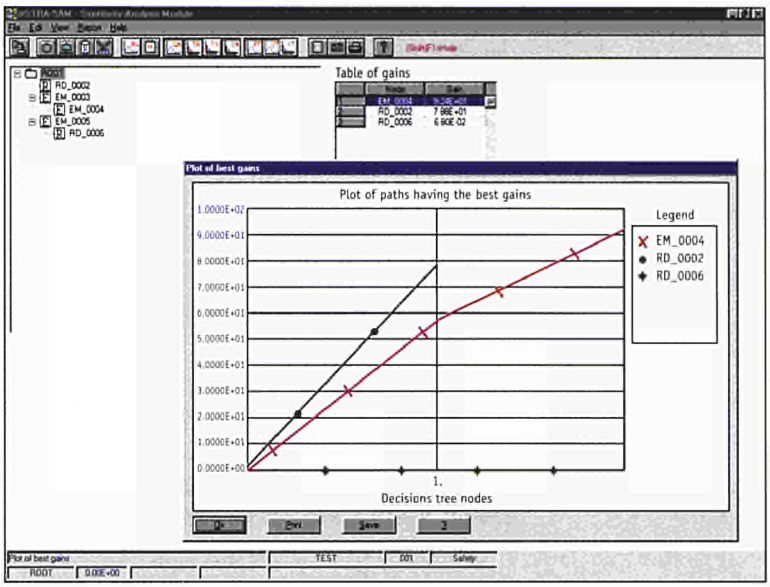


Figure 4.12: Example of a screen-shot of ASTRA-SAM showing the decision tree with different design solutions. Each path corresponds to a tested solution. The effectiveness of each solution is quantified and graphically represented.

STARS 2000 software package for advanced reliability, availability, maintenance and safety (RAMS) analyses of complex technological systems

authors: J.P. Nordvik, S. Contini

ISIS started the development of a major release of its existing STARS software package for Reliability, Availability, Maintenance and Safety analyses of complex technological systems. Preliminary versions of this new release, named STARS 2000, are already available for evaluation. Final release of the software is scheduled for September 1999.
STARS 2000 offers a unique integrated software solution to support on a normal PC-platform both quantitative and qualitative analyses including: Preliminary Hazard Analysis, Hazard and Operability Analysis, Failure Mode, Effect and Criticality Analysis, Fault Tree and Event Tree analyses and Component Criticality Analysis.
The software, fully compatible with the Windows 95, 98 and NT Operating Systems, integrates powerful applications for reliability data management, industrial system representation, advanced import/export procedures with traditional CAD systems, and a powerful report generator to Word and Excel Office Applications.
STARS 2000 is also the major technology at the centre of the CIPRATECH project (Capital Investment Probabilistic Risk Assessment Technology) running under the EU Innovation Programme. The project aimed at the transfer of risk evaluation technologies from the nuclear engineering sector to the capital investment sector. The definition phase of the project was completed in 1998. The implementation phase will start beginning 1999.

[4.22] Contini S., Scheer S., Wilikens M., Cojazzi G., de Cola G. ASTRA: An Integrated Tool Set for Complex Systems Dependability Studies. *Workshop on Tool Support for System Specification, Development and Verification*, Malente, Germany, 1998.

[4.23] Contini S. Recenti sviluppi metodologici nell'analisi degli alberi di guasto - *Convegno Nazionale su Valutazione e Gestione del Rischio negli Insediamenti Civili e Industriali*, Pisa, Italy, 1998.

[4.24] Contini S. ASTRA-FTA: Logical and Probabilistic Analysis Module. ASTRA-PTD: Probabilistic Time Dependent Analysis Module. Knowledge Handbook. *EUR 18727 EN*, 1999.

[4.25] Contini S. ASTRA-SAM: Sensitivity Analysis Module. Knowledge Handbook. *EUR 18728 EN*, 1999.

NATURAL HAZARDS

Natural and environmental disaster information exchange system (NEDIES)

authors: A.G. Colombo, C. Theophili

A project to support DG XI (Environment, Nuclear Safety and Civil Protection) in the area of natural disasters started in 1997. The main aim of the project, called NEDIES (Natural and Environmental Disaster Information Exchange System) is to facilitate the exchange of information among Member State Civil Protection Services on the occurrence and management of natural disasters and produce "lessons learnt reports".

The project, under development at the JRC Ispra with the assistance of the Civil Protection Services of Member States and some other Countries, is in its pilot phase, which will end in the beginning of 1999.

Main 1998 achievements of the project include [4.26, 4.27]:

- Completion of the design of the prototype of an information system to collect and process information on natural disasters and its implementation.
- Compilation and editing of a first set of "event forms" in which endorsed information on natural disasters occurred in the past years in the Member States are reported in as uniform a way as possible.
- Definition of the contents and structure of an "individual report" and a "lessons learnt report" to disseminate in a structured way the information collected and analysed. The "individual report" presents a detailed description of the occurrence and management of each natural disaster considered in the information system. The "lessons learnt report" presents the overall experience gained in the management of all the disasters investigated.

Preliminary territorial risk assessment

authors: F. Bianchi, J.P. Nordvik

ISIS developed for the Civil Protection Authority of the Piedmont Region (Italy) an innovative methodology for the identification and assessment of risks arising from natural and technological hazards over large territorial areas. The methodology focuses on the concept of vulnerability and its evaluation through the use of qualitative and quantitative indicators and indexes. The methodology applies equally for a large range of types of risk sources including floods, landslides and industrial accidents, and consequently offers a single reference framework for the evaluation, comparison and management of all risks that exist in an area. For each type of risk, the methodology provides a step-by-step procedure that leads to the preparation of a risk map with identification and evaluation of all vulnerable regions. These procedures include a detailed definition of all indicators and indexes that need to be evaluated, as well as of the method to perform these evaluations using traditionally available information available from Public Administrations.

[4.26] Colombo A.G., Theophili C. Pilot Project to Establish a Community Information System on Natural Disasters. Interim report of the second phase of the project, 1998.

[4.27] Theophili C. (ed.) - Pilot Project to Establish a Community Information System on Natural Disasters. Interim report of the second phase of the project - Annex: Events forms received from July 1998 to November 1998.

Earthquake predictability

authors: P. Hähner, Y. Drossinos

The dynamics of a generalisation of the one-dimensional spatially discretized Burridge-Knopoff model of earthquake fault dynamics has been investigated analytically and numerically. Plastic deformation of the fault interface has been considered in addition to rigid sliding (creep-slip model) [4.28, 4.29]. The event-size distribution was determined to be scale invariant (self-similar distribution) in agreement with the Gutenberg-Richter relation. Moreover, the power spectral density of the intermittent time series of the average sliding velocity was found to decay algebraically with exponent -1.25.

A cellular-automaton algorithm approximated the dynamics of a fault; an algorithm similar to those used to generate self-organised critical states. The resulting diffusive cellular automaton model was found to reproduce the algebraic correlation in the event-size distribution (Gutenberg-Richter relation) in the presence of dissipation [4.30].
Figure 4.13 presents the seismicity on a fault as a function of time: red dots indicate the locus of epicenters and the black dots sites that failed. Hence, a continuous vertical segment represents an earthquake, the size of which is given by the length of the line. Inspection of the figure shows that events of all sizes may occur, a distinguishing feature of a distribution without a characteristic scale. An analysis of the time series of events generated from the model shows that the occurrence of large events for large time separations follows Poisson statistics [4.31]. However, the short-time behaviour suggests that aftershocks might be correlated to the main event; the applicability of tools developed in the study of predictability in low dimensional chaotic systems is currently under investigation.

Catastrophic risk management

author: A. Amendola

The co-operation with IIASA (International Institute for Applied Systems Analysis) on CRM (Catastrophic Risk Management) is continuing. The management of catastrophic risks requires their assessment via hazard and vulnerability analysis; allocation of resources for their prevention and mitigation; and, strategies for risk burden sharing (insurance and other financial instruments). The research agenda has been confronted with representatives of major reinsurance companies in a workshop on May 11, 1998 at IIASA. Further it was discussed by the presentation of joint papers at important events at

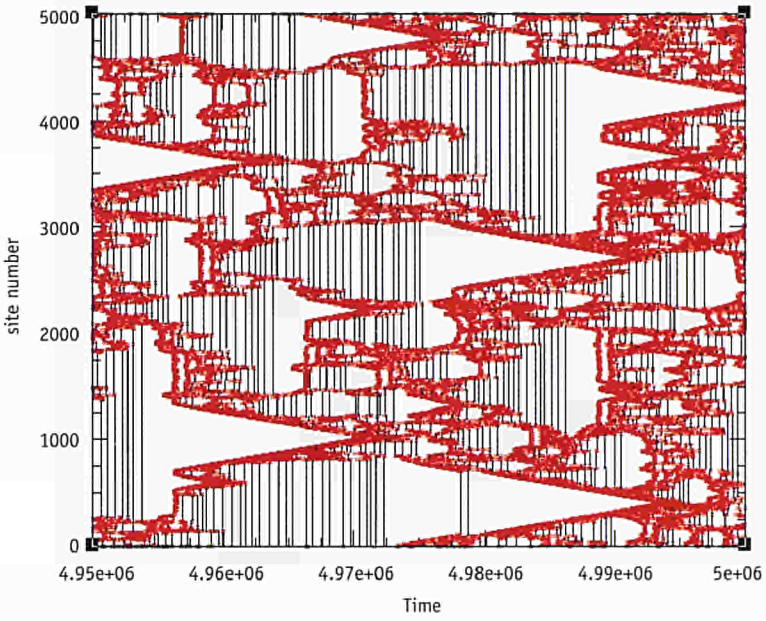


Figure 4.13: Simulated seismicity on a fault as a function of time: red dots indicate epicenters (initiation sites) and black dots sites that failed (shear force greater than threshold).

[4.28] Hahner P., Drossinos Y. Dynamics of a Creep-slip Model of Earthquake Faults. *Physica* A 260, 391,1998.
[4.29] Hahner P., Drossinos Y. Non-linear Dynamics of a Continuous Spring-block Model of Earthquake Faults. *J. Phys. A: Math. Gen.* 31, L185, 1998.
[4.30] Hahner P., Drossinos Y. Scale Invariance and Intermittency in a Creep-slip Model of Earthquake Faults. *Physical Reviewee*, 59, 1999.
[4.31] Hahner P., Drossinos Y. Self-organised Criticality in a Creep-slip Model of Earthquake Faults. Continuum Models and Discrete Systems (CMDS). In *Proceedings of the ninth International Symposium*, Editors E. Inan and K.Z. Markov, pp. 374-387, World Scientific Publishing Co., 1998.

Hanover, Vienna and Odense, organised or supported by the Geneva Association for the study of economics of insurance. The main results are at this stage of methodological nature, both when they refer to the development of stochastic optimisation techniques allowing the study of "optimality" and stability of generated strategies on loss control and risk sharing, and when they refer to the policy and institutional issues linked with CRM.
As far as case studies are concerned, a preliminary analysis of earthquake risk management has been performed after a co-operation with scientists from the Institute for Information Transmission Problems, and the Institute of Lithosphere of the Russian Academy of Sciences. This proved the adequacy for approaching complex realities of the modelling techniques developed.
A more comprehensive case study concerning Italy has been designed together with the Institute of Seismic Risk Research of CNR in Milan, to be performed in 1999.
At the same time a special attention has been given to the Flood Risks in Europe. In particular the support gained from the EC for the organisation of a EuroConference in June 1999, will allow the project to offer a forum:

- to examine the possible influence of global change phenomena, including changes in the climate, land use, population, capital movements, and infrastructure design, on the potential future losses from flood events in Europe, and

- to examine a set of risk management issues to both mitigate flood damage and to improve the spread of the losses, such as the use of models to improve flood risk management; the accounting of long-term flood losses; structural and non-structural options for mitigation; resolution of upstream-downstream conflicts; the use of market instruments and government interventions for flood risk management; the insurability of flood risks and different public/private insurance schemes; the potential for reinsurance and catastrophe bonds to improve flood response and reduce long-term losses.

Natural risks

authors: R. Peckham, C. Böhner

Progress continued to be made in the use of Geographic Information Systems (GIS) as a means to structure, visualise and analyse information on Natural Risks. To advance and make use of JRC expertise in this area the three earthquake catalogues which were developed with the sponsorship of DG XI (Environment, Nuclear Safety and Civil Protection) were made accessible via the WWW, firstly by developing a web-gateway to the ORACLE database on which they are stored, and secondly by developing a gateway to the ARC-INFO GIS.
An implemented and validated system, aimed at providing geographically distributed access to remote data stored in the ORACLE DBMS was developed, and adapted for the earthquake catalogues. The user interface is provided on the World Wide Web, and the system permits the access to data by all authorised users connected to Internet. Users may access information and processing abilities through the ORACLE-WWW-gateway in a controlled interaction mode.

Another gateway permitting access via the WWW to geo-referenced data stored on the Arc-Info GIS has also been developed. Through this the user can select the geographic themes to display and the symbology to use before obtaining the query results in the form of a map image. The two gateways have been made accessible through a single common interface, available at the address: http://taws08.jrc.it/gis-gateway/eq96.html

The work in 1998 consisted of the completion of the WWW interfaces to the catalogues with the inclusion of thematic layers. Also finalised in 1998 was a Common Interface to the two web gateways: the ORACLE gateway and the GIS gateway.
These developments were more fully described and presented to the EOGEO98 conference held in Salzburg [4.32].
Finally preparations have been made to use the GIS to perform spatial analyses relating the Earthquake events to population and landcover information for the Iberian Peninsular.

[4.32] Mattarelli M., Boehner C., Peckham R.J. Web Access to Earthquake Catalogues. Paper presented at EOGEO 98, Salzburg, February 1998.

SOFTWARE FOR PROCESS INDUSTRIES

RELIEF

author: J.S. Duffield

RELIEF is a user friendly computer package specially developed to ease the task of designing, and of understanding the phenomena associated with, emergency pressure relief systems for batch-type reactors and storage vessels commonly used in the chemical process industry. This software is used throughout Europe, Japan and Mexico. At the 9th International Symposium on Loss Prevention and Safety Promotion in the Process Industries in 1998, the first European Process Safety Centre's award presented to the individual making "a significant contribution to process safety in Europe", was won by Stuart Duffield for his work in producing the RELIEF computer package.

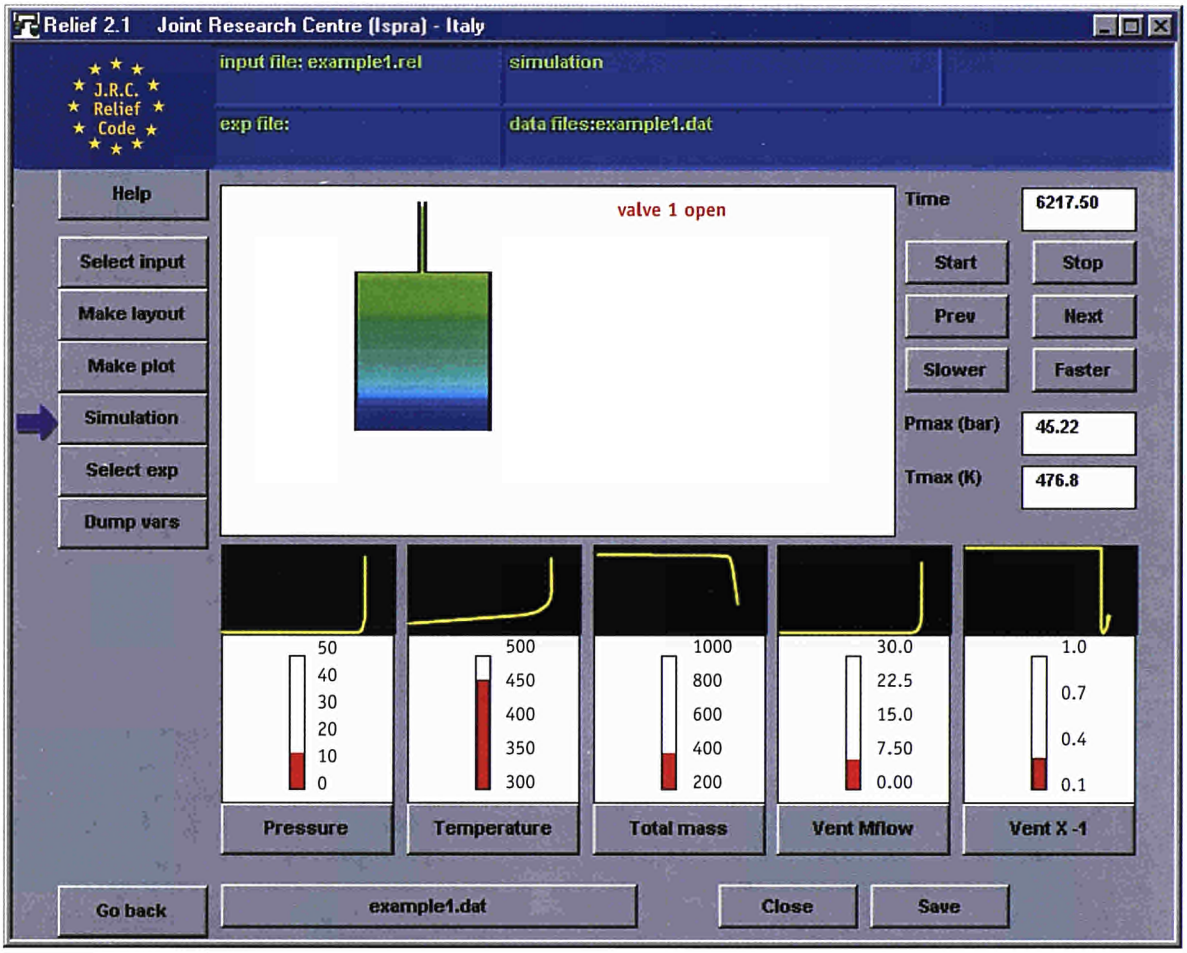


Figure 4.14: Simulation option of RELIEF.

32 Thematic network on hazard assessment of highly reactive systems (HARSNET)

ISIS contact: J.M. Zaldívar

Despite tremendous investments to improve the safety of chemical plants, the mere number of accidents and their consequences are still alarming. In general, severe accidents due to runaway reactions can be grouped into one single class of scenario: if, for some reason the rate of heat generation by chemical reaction exceeds the rate of heat removal of the cooling system, the temperature of the reacting mass will begin to rise. This in turn will cause an increase of the heat generation rate. This positive feedback mechanism results in an auto-acceleration behaviour of the heat generation rate, producing a large amount of heat in a very short time with the possibility of triggering off side and chain reactions that eventually can lead to explosion and the destruction or inoperability of the plant. This thematic network intends to create a wide forum of European universities, research centres and chemical companies in which established and developing knowledge about reactive chemicals hazard assessment would be examined in order to prepare recommended techniques and methodologies; to analyse experimental techniques and methodologies, and to transmit this knowledge to small- and medium-sized chemical companies.

A related activity from this network is the AWARE (Advanced Warning Against Runaway Events) Project. This project aims at improving the quality, safety and reliability and reduce accidents in chemical plants by developing and testing a new device for early warning detection of runaway events, based on the results of a research carried out at ISIS on the application of chaos theory techniques to discontinuous reactors [4.33, 4.34]. A prototype version has been built-up and tested during 1998, see Figure 4.15. The results show that the device is able to detect in advance the onset of the runaway and also the stirrer breakage malfunction by measuring reactor and jacket temperatures.

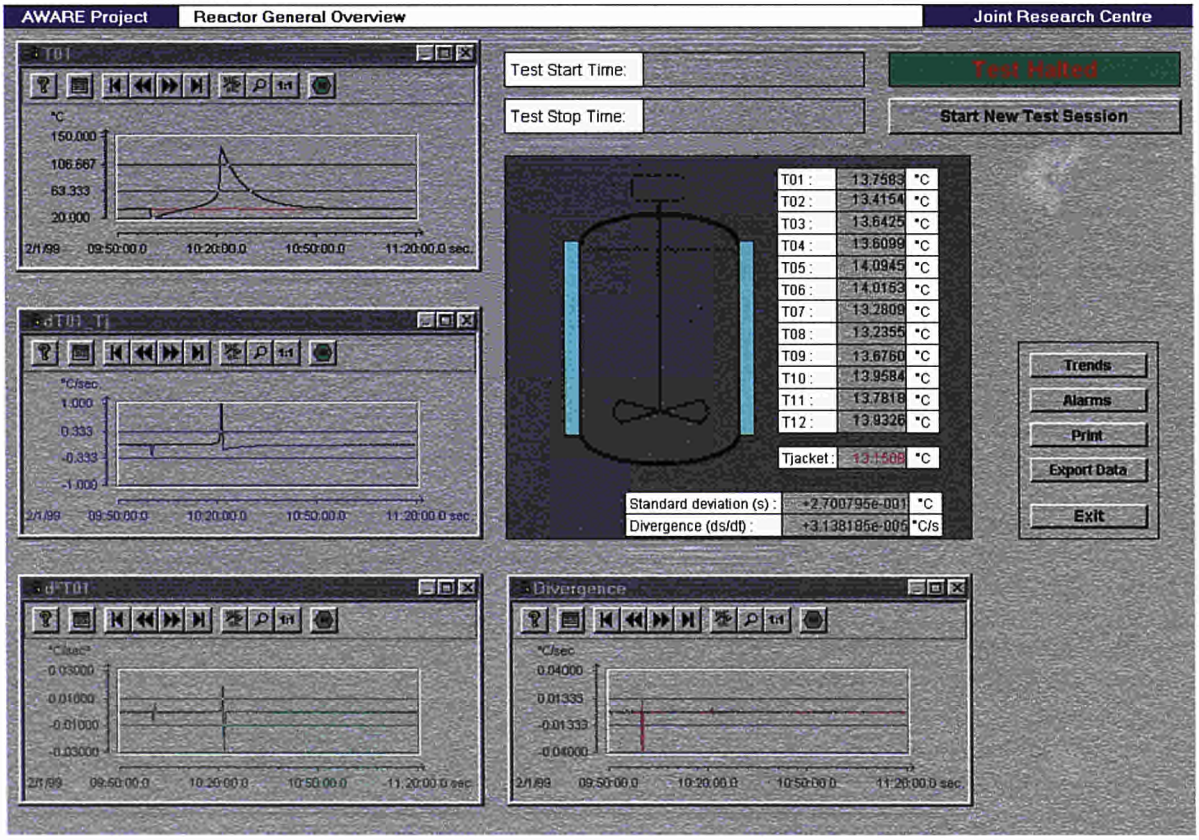


Figure 4.15: Advanced warning against runaway (AWARE): General overview of the reactor.

[4.33] Zaldívar, J.M. and Strozzi, F. On-line early warning detection system of runaway initiation using chaos theory techniques. N° 97108772.1., 1997.

[4.34] Strozzi, F., Zaldívar, J.M., Alós, M.A., Westerterp, K.R.D. Towards on-line early detection of runaway initiation using chaos theory techniques. *Proceedings of the 9th International Symposium of Loss Prevention and Safety Promotion in the Process Industries*, 4-7 May, Barcelona, Spain, pp. 708-717, 1998.

33 Scientific model evaluation of dense gas dispersion models (SMEDIS)

ISIS contact: J. Wurtz

The aim of the SMEDIS project is to perform a scientific model evaluation (SME) of "state-of-the-art" dense gas dispersion (DGD) models with the capability of dealing with both "simple" situations and, in particular, with complex flows involving aerosols, topography and obstacles. This involves an examination of the model theory and methodology, determination of the limits of applicability, an assessment of the implementation and validation comparisons against data.

The specific objectives of the SMEDIS project are:

- *Develop and further test a protocol for a scientific model evaluation (SME) of dense gas dispersion (DGD) models.*
- *Carry out a SME of all currently available DGD models in Europe, using this protocol with particular emphasis on the complex effects of aerosol formation, complex terrain and obstacles.*
- *Leave in place a methodology for scientific model evaluation.*

A finalised version of the test protocol has been elaborated, and the validation exercises of the models have been initiated.

34 Advanced Design Methodologies for Improved Performance of Gas-Liquid Reactors (ADMIRE)

ISIS contact: H. Städtke

The main objective of the ADMIRE project is to develop advanced methodologies for the design of gas-liquid chemical reactors which are extensively used for chemical synthesis routes in the Petrochemical and Chemical industries. The methodology applied is based on the further development and application Computational Fluid Dynamics (CFD) tools allowing a detailed calculation of complex local flow and related turbulent phenomena. It is expected that these techniques will replace in the near future present highly empirical design methods which largely rely on expensive experimental verifications.

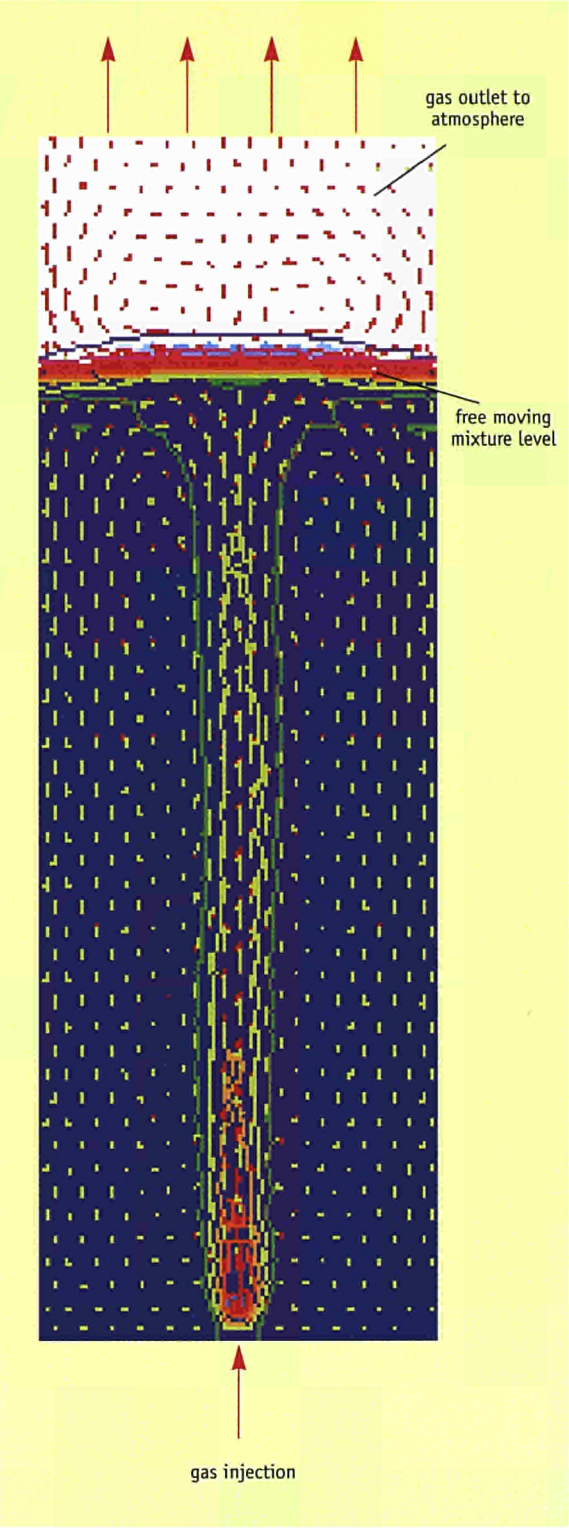


Figure 4.16: BASF flat bubble column test case: re-circulation pattern in bubbly regime below mixture level and counter-current flow patter in gas space, overlay of gas volume concentration with local mass fluxes for liquid (yellow) and gas (red), iso-colors: pure liquid (dark blue) to pure gas (light blue).

The main industrial benefits will include:

- *less time consuming and lower cost design due to reduced need for experiments*
- *cost savings due to better process optimisation resulting in higher yields*
- *improved process control leading to fewer, potentially hazardous accidents*
- *reduced environmental impact due to higher selectivities and less waste.*

The major tasks of the project are related to an improved modelling of governing two-phase flow processes including the description of fluid-particle interaction like bubble coalescence and break-up, handling of bubble size distribution, two-phase dispersion and turbulence phenomena and their coupling with heterogeneous chemical reactions.
The specific contribution of the JRC Ispra is the development and assessment of a new model for the transport of Interfacial Area Concentration (IAC), a parameter that largely governs the coupling of the two phases and the chemical reaction kinetics. The IAC model has been first implemented into the JRC 2-D Advanced Two-Phase Flow (ATPF) code and a number of assessment calculations have been performed for the model verification. An example is given in Figure 4.16 showing prediction of volumetric gas concentration and re-circulation pattern in a flat bubble column test as was performed at BASF.
As the primary software tool the AEA-Technology CFD code "CFX-4" was selected by the project consortium which by the end of the project in February 2000 should incorporate all newly developed models and solution strategies with regard to the two-phase flow dynamics, turbulence and heterogeneous chemical reactions.

35 Explosion model evaluation project (EME)

ISIS contact: B. Worth, T. Huld

The EME project supported a previous EC initiative designed to improve the culture in which explosion models are developed and used, to ensure that models covering all aspects of major hazard evaluation are up-to-date with technical developments and that models are utilised by personnel adequately trained in their applicability and functionality. The two main objectives of the EME project were defined as:

- *to develop protocols and standard test cases which form the framework of a formal procedure for the evaluation of models which predict vapour cloud explosions and their consequences*
- *to apply the protocols and test cases to available models.*

To achieve these objectives, a number of interrelated activities were undertaken. The first task was to identify those models available in Europe currently used for predicting (1) vapour cloud explosions, (2) the received loading on a structure and (3) the dynamic response of the structure subjected to blast. Secondly, model evaluation protocols and questionnaires were developed for each main theme, each protocol giving clear guidance as to how models in general should best be evaluated. These protocols then formed the basis for an evaluation exercise carried out as part of the project. Thirdly, various test cases were selected, audited and documented for the purpose of specific model evaluation. From a number of potential test cases, three were selected and fully documented for each theme. Fourthly, modellers from industry, research and academia were invited on a voluntary basis to participate in predicting these various test cases, allowing an independent evaluation of the protocols and test case documentation. Results of this evaluation exercise were the subject of a two-day EME Final Workshop held in Aberdeen and London in June 1998 to disseminate project results, and provide feedback to finalise the protocols.
The EME project, which was a two-year shared-cost-action under the Environment and Climate Programme of FP4, ran from October 1996 to September 1998. After a successful completion of the project, final documentation has been issued and an Internet site established by the project co-ordinator (see http://www.steel-sci.org/eme).

36 Investigations of viscous venting and treatment of releases (INOVVATOR)

ISIS contact: S. Morris

To complement the very limited experimental database on high-viscosity multiphase flows, the INOVVATOR projet performs a number of experiments desiged to fill certain critical knowledge gaps such as liquid-vapour distribution in reator vessels, the pressure drop characteristics of safety valves and associated pipe systems and corresponding mass discharge rates.

Safety of civil engineering and cultural heritage structures

editor: V. Renda

The European Commission is strongly engaged in research and development to support the protection of Europeans from the effects of strong earthquakes. To this end, ISIS is in charge of the European Laboratory for Structural Assessment (ELSA), a unique facility in Europe for the execution of pseudo-dynamic seismic tests on large-scale models of structures. Through its theoretical and experimental work, ELSA contributes to the validation of the European norms and standards (Eurocodes) for construction in seismic zones and the development of innovative technologies and techniques for the mitigation of the seismic effects on both civil and cultural heritage structures. Tests at ELSA are performed on large-scale models of civil buildings and bridges, and also of parts of monuments; the latter are built in the laboratory with materials and criteria similar, as far as possible, to the ancient constructions. The contribution of ELSA is given through institutional work, competitive actions in collaboration with international networks and validation assessments and tests carried out for third parties on specific relevant projects.

Eurocodes

author: P. Negro

The ELSA Laboratory plays an important role in providing experimental data to be used for the calibration and verification of the Eurocodes, in particular with reference to the Eurocode 8, the harmonized code for Earthquake Resistant Design of Structures.
During the last year, a number of experimental activities have been conducted, with the aim of proposing improvements to those chapters of the codes which may deserve some improvement. This included the activities for the definition of damage criteria for welded steel connections (project STEELQUAKE) [5.1], a problem that has been highlighted by the damage resulting from recent strong earthquakes in California and Japan.
Other experimental activities were aimed at including the effects of local geological conditions in the design process, and resulted in unique large-scale tests on soil-foundation systems (project TRISEE) [5.2].
Two projects were conducted to test the performances of innovative energy dissipation systems for the seismic protection of existing structures (see REEDS) and monuments (see ISTECH).

Fig. 5.1: Two-storey concrete frame structure to test rehabilitation techniques for existing non-ductile structures.

In addition, experiments were performed to assess possible rehabilitation techniques for existing non-ductile structures (Figure 5.1), for which it is accepted that the relevant chapter in Eurocode 8 is not yet adequate in terms of practical guidelines.
The process of adoption of Eurocode 8 is progressing, and has reached the phase of the evaluation of the comments received so far. Even though Eurocode 8 is bound to its hopeful conversion from Provisional European Norm (ENV) into a European Norm (EN), the pre-normative work has not been discontinued. In the framework of the network "Innovative concepts for new and existing structures" (ICONS), ELSA has become active in the research for the new generation of design codes. This includes the assessment of a completely different approach in seismic design, the so-called Displacement Based Design, which may completely change the philosophy of seismic design procedures in the future.

37 Development of innovative techniques for the improvement of cultural heritage (ISTECH)

ISIS contact: V. Renda

ISTECH investigates the possibility of using the Shape Memory Alloys (SMAs) for the realization of mechanical and seismic protection systems for cultural heritage structures based on devices having intrinsically energy dissipation capabilities [5.3].
SMAs materials are characterised by super-elasticity allowing energy dissipation through a phase change from Austenite to Martensite and vice-versa. This stress-strain cycling does not produce any material damage and is always performed in traction, allowing the use of cables for the realisation of the devices.
ELSA contributed to the project through some relevant theoretical and experimental tasks mainly oriented to material characterisation for this specific engineering purpose and full-scale tests of masonry walls. The experimental campaign has been done on models both unprotected and protected with the innovative system in order to quantify the benefit due to the techniques.

References

[5.1] Taucer F.F., Negro P., Colombo A. Steelquake, Cyclic Testing of the Steel Frame. *Special Publication, No. I98.160*, Ispra, 1998.
[5.2] Negro P., Verzeletti G., Molina J., Pedretti S., Lo Presti D., Pedroni S. Large-Scale Geotechnical Experiments on Soil-Foundation Interaction. *Special Publication No. I.98.73*, Ispra, 1998.
[5.3] Renda V., Verzeletti G., Magonette G., Molina G., Tirelli D., Bono F. Activities of the European Laboratory for Structural Assessment for Seismic Risk Reduction in Europe - *Proceedings of the Second International Conference on Earthquake Hazard and Seismic Risk Reduction*, Yerevan, Armenia, 15-21 September 1998.

Figure 5.2 shows the wall incorporating the cross-bracing system including the SMAs devices and Figure 5.3 shows the results obtained in terms of energy dissipated by the walls (unprotected and protected) and the devices [5.4].
The unprotected wall has been loaded for increasing intensities of the assumed reference earthquake signal. The model showed stability until 300% of the signal, while the protected wall reached 500% of the signal with much greater energy dissipation. The total energy dissipated by the SMAs devices has been of about 30% of the total energy of the system. These results showed the capability of the system to offer a good increment of protection to the tested masonry walls.

38 Optimisation of energy dissipation devices, rolling systems and hydraulic couplers for reducing seismic risk to structures and industrial facilities (REEDS)

ISIS contact: G. Magonette

Earthquake protection of important buildings, bridges, potentially hazardous industrial plants and vital equipment is of key importance both on safety and economical grounds. REEDS focuses the efforts of manufacturers, developers and end-users of anti-seismic devices towards identifying methods to augment the options currently available and therefore greatly increase the possibility that economic seismic protection can be provided to any particular structure, plant or equipment.
The first task of the project - the identification of seismically vulnerable structures and equipment - leads to the adoption of a reinforced concrete frame civil structure (see Figure 5.4). The choices now available to meet seismic criteria for this type of structure are mainly based on the strengthening of the design. The introduction of viscoelastic energy-dissipative (VED) devices brings a "soft" alternative to the well known strengthening method or more recent seismic isolation technology. Seismic regulations are relatively recent and consequently many buildings have no or very little protection. Considering that most buildings are around 100 years old, then seismic retrofitting is potentially a large market, and VED devices may well be the most economic solution in many cases.
To operate efficiently during an earthquake, the VED devices need to experience a minimum amount of displacement. Therefore their total stiffness per floor must be of the order of the floor stiffness of the building. Consequently, the use of these devices could be difficult for very stiff concrete structures, especially

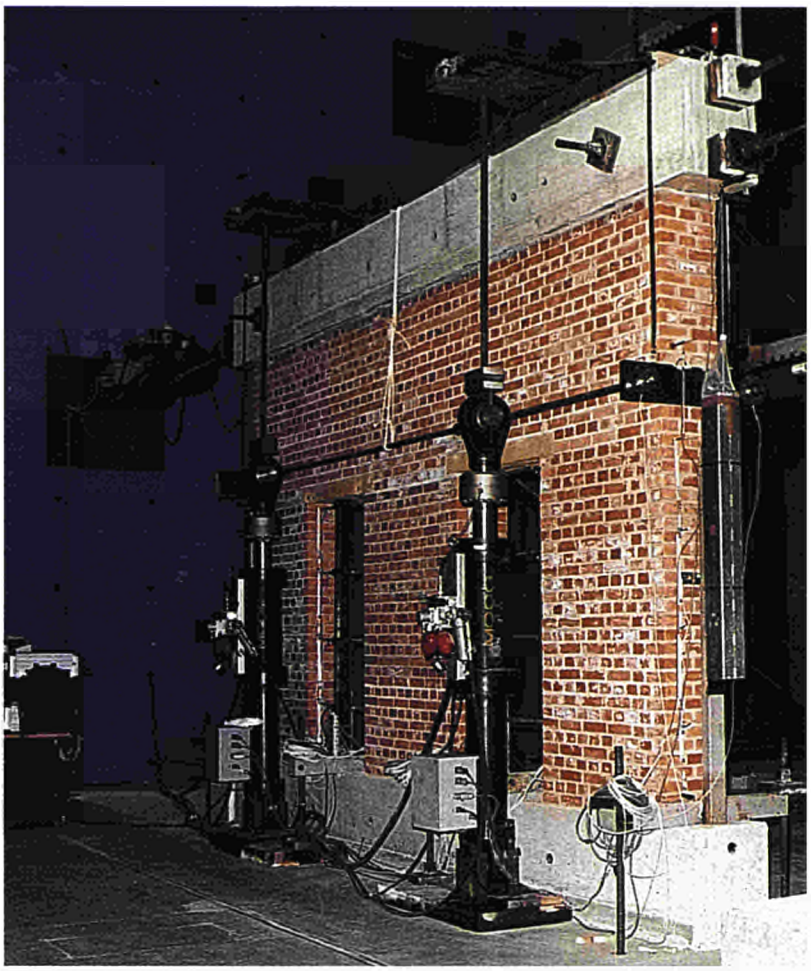


Figure 5.2: Masonry wall protected with Shape Memory Alloys (SMA) devices.

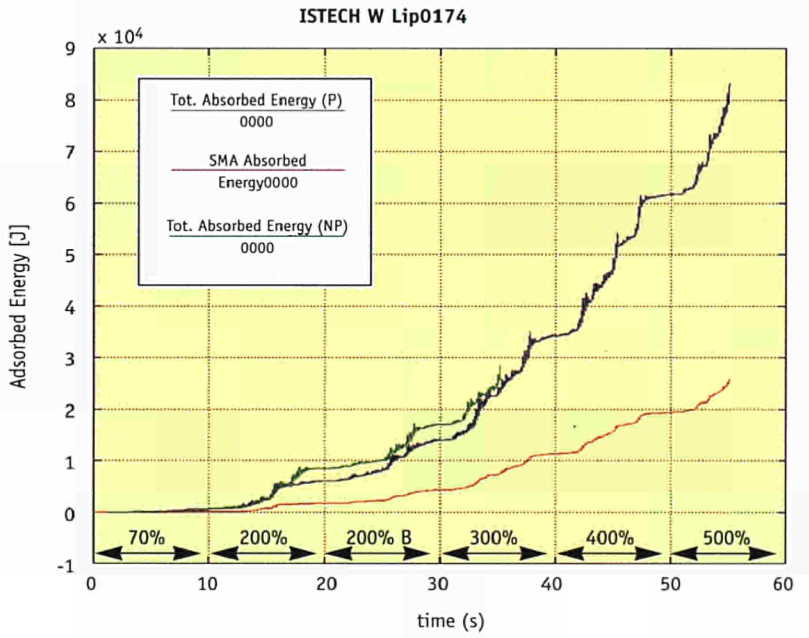


Figure 5.3: Energy dissipated by different walls for successive increasing earthquakes. (Green = Unprotected; Red = Shape Memory Alloys (SMAs) devices; Blue = Wall protected with SMA devices;).

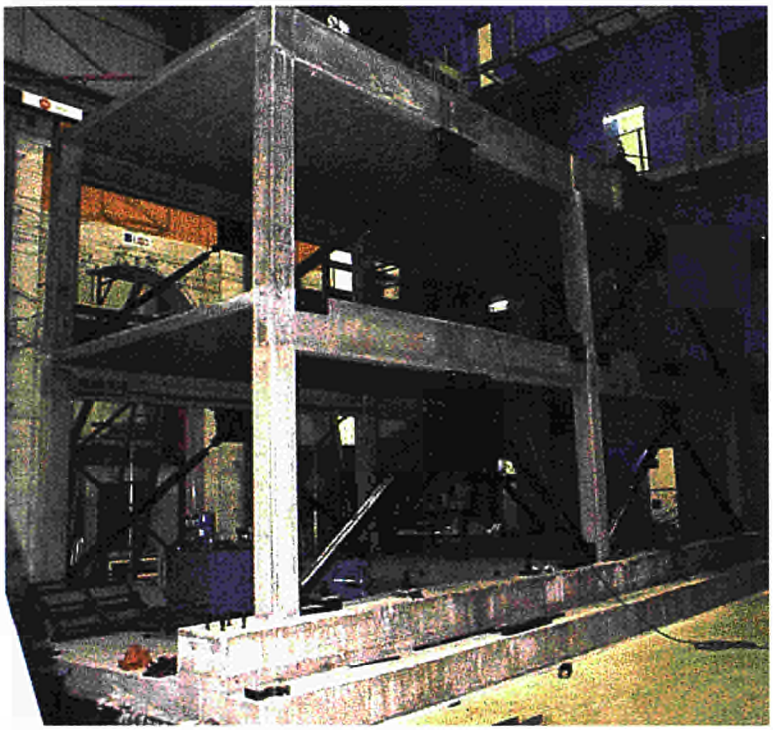


Figure 5.4: Large-scale model of the civil building equipped with anti-seismic protection used for the earthquake simulation experiments at the ELSA laboratory.

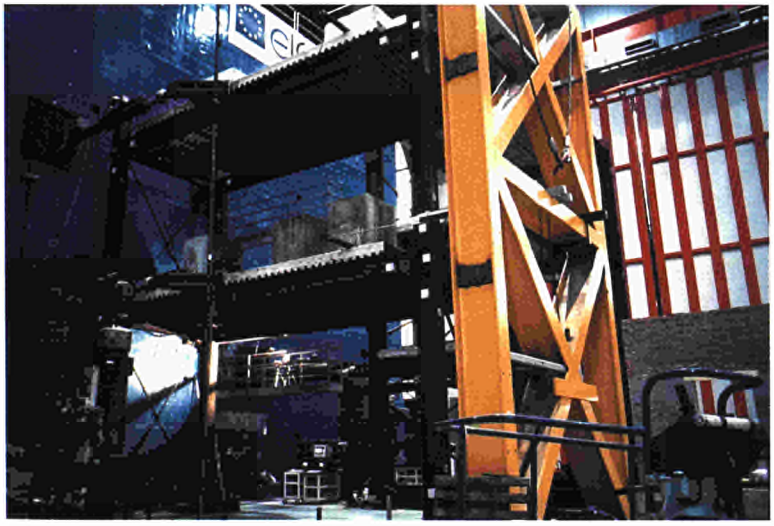


Figure 5.5: Two-storey one-bay steel frame for large amplitude cycling tests.

those containing shear walls. Nevertheless, with frame structures that are quite common in seismic areas of Europe, the technical study has proved that reinforced concrete frame buildings designed initially for non-seismic areas may be up-graded by incorporating viscoelastic dampers to respond without damage to earthquakes specified in Eurocode 8. The devices can indeed provide an alternative protection strategy for such buildings. The dampers raise the stiffness between floors, the increase itself contributes to the reduction in the response. However, the inherent damping of the devices greatly reduces the response. The PsD tests carried out at ELSA on the large-scale civil buildings have shown that when the structure is protected with the devices it responds two times better to earthquakes than the bare structure.

39 Improved assessment of steel building performance during earthquake (STEELQUAKE)

ISIS contact: P. Negro

After the Northridge 1994 and Kobe 1995 earthquakes it was observed that many steel frame buildings that did not show apparent external damage exhibited significant deterioration at the level of their connections.
STEELQUAKE was set up for the improved assessment of the performance of steel buildings during earthquakes. The aim of the programme was to allow the full design of welds, thickness of components and dimensions of steel frame connections, taking into account the duration of the earthquake and the number of corresponding cycles to be supported in the dissipative zones. That is, to introduce a definition of the q factors (the ability of steel structures to dissipate energy) depending on the considered time-history. To achieve the above objective, full scale testing of welds and of beam to column connections were carried out on different specimens; shaking table and pseudodynamic tests have been performed to provide complementary experimental data concerning the global behaviour of steel frames.
The work performed at ELSA [5.5] consisted on large-amplitude cyclic tests on a real scale two-storey one-bay steel frame welded structure (Figure 5.5). Damage indices computed for the connections at the local level will be related to damage indices for the

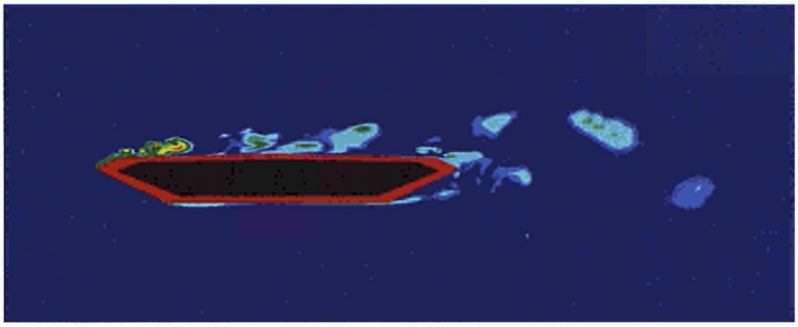
[5.4] Bono F., Tirelli D., Verzeletti G., Molina J., Renda V. Shape Memory Alloy crossbracing of brick masonry walls: Cyclic tests of a large-scale model and numerical analyses - *Proceedings of MONUMENT-98 Workshop on Seismic Performance of Monuments*, Lisbon, Portugal, November 12-14 1998.
[5.5] Taucer F.F., Negro P., Colombo A. Steelquake: Cyclic Testing of the Steel Frame. *Special Publication, No. I.98.160*, Ispra, 1998.

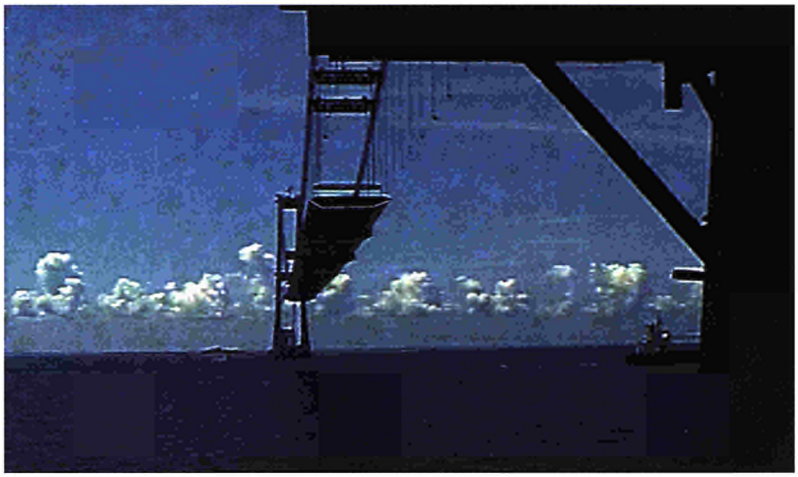
structure at a global level. This is done to derive a consistent definition of the q factor that represents the behaviour of both the connections and the structural configuration of a moment resisting frame in terms of a given number of cycles of specified amplitude. In this respect, an expression to assess the cumulative damage due to cyclic loading of welded connections is proposed, based on the histories of absolute and relative rotations of the plastic hinge.

40 Fluid structure interaction in structural design (FSI-SD)

ISIS contact: K. Mehr

The goal of the Fluid Structure Interaction in Structural Design project is to make the design of fluid exposed structures more accurate and efficient utilising advanced modelling techniques on high performance computing systems as a complement to existing methods.
In wind engineering, the design of the structures relies on wind tunnel testing. The FSI-SD project should allow one to study parameters specific to the design prior to the use of wind tunnels, thus reducing the reliance on expensive and time-consuming testing and model creation (Figure 5.6).
The offshore industry is exploring the deep seas; hence an understanding of the hydrodynamic forces exerted on the structures is important for the design. The FSI-SD project improves precision in design predictions.
ISIS has contributed to the coupling of the two physical domains modelled. The fluid domain is calculated by means of a CFD code. The structural domain is calculated by means of a CSD code. Consistency in the physics on the interfaces is required. Furthermore ISIS has set up the re-meshing methods needed to "synchronise" the two domains. These have been based on sub-domains to save on computing time.





Figures 5.6: (a) Simulation of vortex shedding on the Great Belt Bridge linking the two main Danish islands.
(b) The Great Belt Bridge under construction showing the cross-section as modelled in (a).

41 3D site effects of soil-foundation interaction in earthquake and vibration risk evaluation (TRISEE)

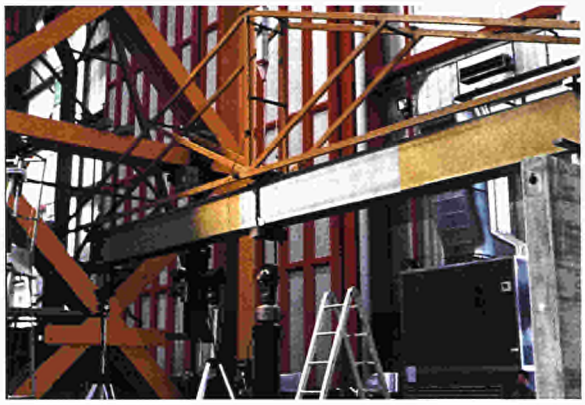
ISIS contact: P. Negro

The experimental activity of TRISEE has extended the field of expertise of ELSA to cover soil mechanics problems. In TRISEE the tests were designed to provide the necessary validation data for the calibration of new and existing computer models, and to obtain a practical assessment of the permanent deformations and bearing capacity of the soil-foundation systems [5.6].

Figure 5.7: Large-scale soil specimen for soil-foundation interaction tests.

Two large-scale soil specimens were constructed. The tests were performed with different relative densities (40% and 80%). The set-up consisted of a model of shallow foundation resting on a large volume (4.6m x 4.6m, 3 m deep) of sand of known and uniform properties. To obtain the required relative densities, a special device for the deposition was designed and constructed. This consisted in a travelling laminar spreader, which moved laterally at constant velocity above the specimen (Figure 5.7). By selecting the width of the laminar opening it was possible to achieve the uniform target density for the constant travelling velocity and for a large range of falling heights. The reconstruction of such a large specimen had never been attempted before. De-aerated water was then slowly flushed from the bottom to obtain a high degree of saturation.

The foundation was subjected to a series of excitations, including earthquake-like forces and cyclic deformations up to failure. The experimental activity provided an unprecedented wealth of results to be used in the calibration of the numerical models for the assessment of the effects of irregular soil configurations. This will finally yield a series of simplified rules to be eventually proposed for inclusion in Eurocode 8.



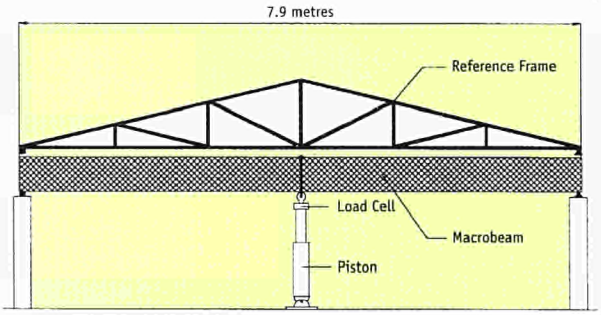


Figure 5.8: (a) Photo of a full-scale, 8-metre carbon/glass fibre-reinforced macrocomposite beam in the test set up.
(b) Schematic representation of the load set-up for the 8-metre macrocomposite beam.

Macrocomposite structural systems

author: E. Gutiérrez

There has been an increase in the use of Fibre-Reinforced Composites (FRC's) as new, integral, structural elements in standard civil engineering. Most of their use is on applications where the load demand is not particularly high. However, recently, there has been much interest from the civil engineering community in these materials, believing that they could be used to better effect in standard civil engineering applications; for example, in the design of composite formwork beams or light weight flooring systems.

The term structural composite element, in civil engineering, can mean any combination of materials (but usually steel and reinforced concrete) that contributes to the main structural capacity. The term macrocomposite, referred to herein, consists of any element that combines the use of concrete and FRC's. The idea of designing and testing an advanced composite reinforcing-formwork for the production of a macrocomposite beam was suggested as a topic on the research theme dedicated to the application of composite materials to civil engineering. As a result an 8m long macrocomposite beam system was manufactured and tested to failure at the ELSA laboratory (Figure 5.8). The project was conducted in collaboration with a number of European companies from both the civil and advanced composites manufacturing engineering environments.

The concept consists in substituting the standard, steel or wooden, formwork usually used to manufacture reinforced concrete structures, with one made form FRC's. The FRC formwork would not (as is normally the case) be dismantled once the concrete was set, but rather, would be bonded to the concrete, thus acting as tensile reinforcement in substitution

[5.6] Negro P., Verzeletti G., Molina J., Pedretti S., Lo Presti D., Pedroni S. Large-Scale Geotechnical Experiments on-Soil-Foundation Interaction. *Special Publication No. I.98.73*, Ispra, 1998.

[5.7] Gutiérrez E., Di Salvo G., Bono F., Verzeletti G. Preliminary Report of the Tests Conducted on an 8m Beam Manufactured with a Hybrid Composite Formwork. *JRC-ISIS Technical Note No I.98.122*, 1998.

of the usual steel reinforcement bars and stirrups. The key engineering concepts examined in the test campaign were:

- Structural failure modes.
- Creep and relaxation characteristics.
- Optimization of overall stiffness by proper use of material properties.

The structural performance was found to be particularly good for structural safety because even if beam failure propagated catastrophically, the beam withstood, quasi-elastically, a load approximately 2.5 times heavier than the design load of an equivalent pre-stressed concrete beam [5.7]. When some delamination between the concrete and the composite formwork occurred, it was easily repaired and the beam subsequently re-tested.

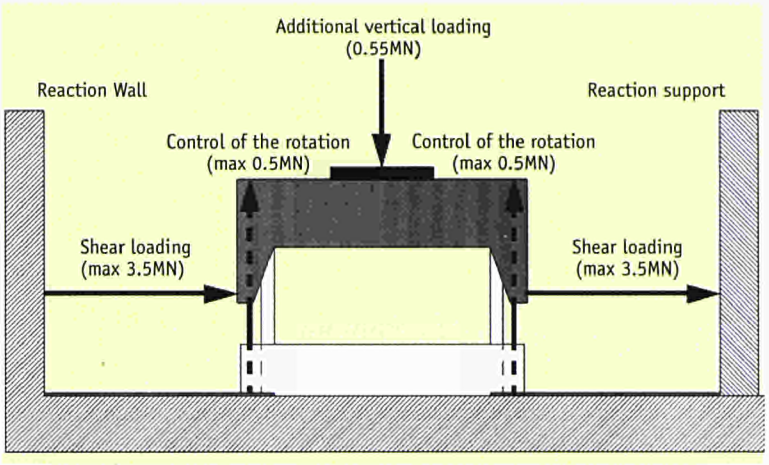


Figure 5.9: Schematic representation of the loading device and the principle for testing performance of walls in the SAFE Programme.

The SAFE programme

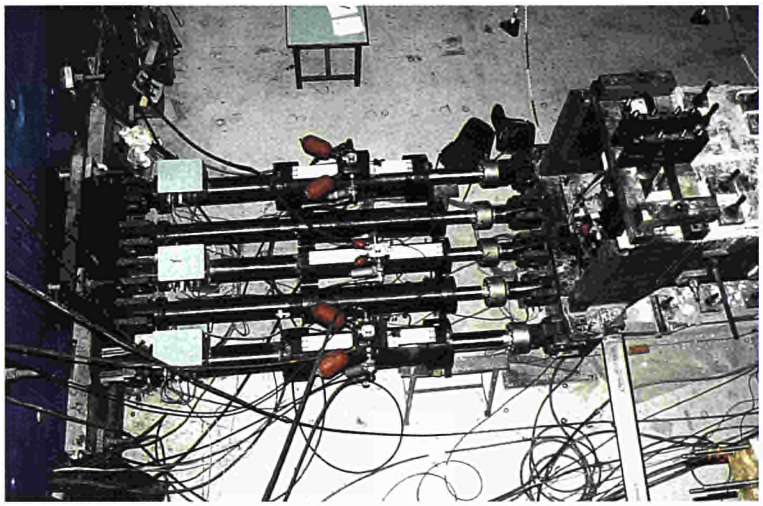
author: P. Pegon

The SAFE (Structures Armées à Faible Elancement – Reinforced structures with small aspect ratio) programme is a third-party work. Its purpose is to specify inherent margins to the nuclear seismic practice for shear walls and to establish data for calculations and verification beyond the elastic-linear range. This involves, force/displacement hysteretic loops, relationships between crack opening and shear distortion, characterisation of the limit state and in particular the shear capacity loss, ductility and behaviour coefficients, etc. The programme is co-financed by the French COGEMA (Compagnie Générale des Materiaux) and EDF (Electricité de France).

For ELSA, the SAFE program consists in series of pseudo-dynamic tests on various reinforced concrete shear walls [5.8]. The differences between each series of tests are related to the steel ratio of reinforcement, the natural frequency of the wall and the vertical loading. Each series consists in submitting the wall to an accelerogram with various increasing level of amplitude, the first level corresponding to the design earthquake.

The client provided the geometrical characteristics of the walls to be tested. In the loading device (Figure 5.9) to induce pure shear in the wall, the rotation of the top beam is prevented. The maximum horizontal of 7MN has been applied at the level of the gravity centre of the wall.

The lateral loading is applied by means of 2x5 hydraulic



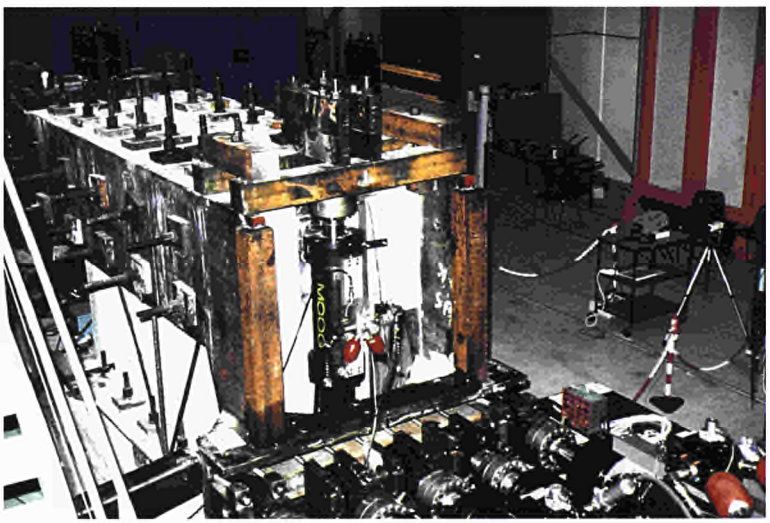


Figure 5.10: (a) View of the left-hand side and (b) is the right-hand side of the experimental set-up of the loading device used in the SAFE programme illustrated in Figure 5.9.

jacks. Two of them, acting as master jacks, one on each side of the specimen, are controlled in displacement (Figure 5.10).
Most of the pseudo dynamic (PSD) tests have been performed using the continuous method. In this new methodology, each time step is subdivided in a large number of micro-steps of effective duration 1ms and the measure of the load in the actuator is then perfectly synchronised with the prescription of the displacement. The monitoring of the crack openings has been performed using transducers glued to the wall during the experiments, as soon as some interesting cracks appeared and developed.
In support to the program SAFE, an on-line method of extraction of the frequency and equivalent damping has been developed [5.8] to identify a model of the transfer function of the structure and then to derive its natural frequency and damping [5.9].

42 Inverse problems in structural and material mechanics (INVERPRO)

ISIS contact: M. Whelan

The mechanical characterisation of materials and structures in service is central to understanding their behaviour and to predicting their service life. Moreover, in situations where a material or structure has modified its mechanical properties during service, measurement and analysis are necessary if accurate predictions are to be made regarding their remnant service life and associated operational safety. For example, many of Europe's larger bridges and dams are approaching the end of their original design life and thus critical decisions must be taken regarding their structural integrity and the possible risk in continuing to operate them without intervention. This project, concerning inverse problems in structural and material mechanics, aims at the development and application of advanced numerical and experimental techniques in the characterisation of complex composite materials and structures.
The project is supported by the DG XII Programme on International Co-operation (INCO-Copernicus) and thus involves the participation of partners from central European countries. The work-programme is directed at solving two main problems. This first problem concerns the characterisation of the complex inelastic behaviour of non-homogeneous materials (e.g. polymer matrix composites, advanced concrete etc.). ISIS is involved in the application of optical fibre sensors to the measurement of internal strains in material specimens. These optical sensors are based on intrinsic Bragg-type gratings written into the core of an optical fibre where the central wavelength of the reflecting light from the grating is proportional to the strain applied to the fibre. Also, Digital Speckle Pattern Interferometry in being used to measure the surface deformation of mechanically loaded specimens or components with very high resolution and in a non-contact manner. The data derived from these investigations in then used to identify or calibrate parameters in a pre-selected complex constitutive model using modern system identification techniques. These models then form the basis for the implementation of various numerical methods (e.g. finite element analysis, finite difference methods etc.) for the simulation of the behaviour of structures and the prediction of residual life. The behaviour of fibre reinforced composites (e.g. reinforced concrete) that are widely used in civil and structural Engineering are being studied in detail with emphasis on interface interactions, wear and damage. The second problem concerns detection and monitoring of damage and defects in structures. Hybrid analytical-experimental methods are being developed for the identification of cracks and delamination damage in multi-layered structural elements, concrete dams and gas transportation pipelines. Predictions are compared with data obtained by actual monitoring of structures during their service lifetime. The overall aim is to improve on monitoring methodology by combining existing and novel metrology instrumentation with numerical techniques for system identification.

43 Punch and bulge testing of small specimens

ISIS contact: M. Whelan

Punch and Bulge testing is an emerging technique in many areas of engineering where it is necessary to reliably measure the mechanical properties of materials of which there is little quantity available. For example, in the development of new ceramic materials, it is often the case that synthesis of these materials on a

[5.8] Molina F. J., Pegon P. Identification of the Damping Properties of the Walls of the SAFE Program. *JRC Technical Note no. I.98.35*, 1998.
[5.9] Dalbera J., Gallois C., Pegon P. Shear Test of Reinforced Concrete Walls Safe Program. In *Proceedings of the International Symposium on Current Issues Related to Nuclear Power Plant Structures, Equipment and Piping*, Ed. C.C. David Tung, North Carolina State University, Raleigh, USA, 1998.

laboratory scale only produces limited amounts. In the assessment of the remnant life of power stations it is often necessary to conduct mechanical tests on the different materials used in critical components and this is possible by extracting a small sample of material without compromising the integrity of the structure. In most cases, the geometry and size (typical dimension 2 to 10 mm) of the volume of raw material available does not allow the machining of specimens which satisfy the limits for minimum size and optimum geometry recommended by recognised testing standards (e.g. ISO). Punch and Bulge testing methods have been developed specifically to test miniature disk specimens and involve the indentation of a small thin plate of material (typical a disk of diameter 3 to 10 mm, 0.5 mm thickness) which is clamped about its edge.

Early in 1998, ISIS completed a three year International Co-operation (INCO-Copernicus) project with partners from Central European countries related to Small Punch techniques for residual creep life measurement. The activity was continued with the support of the Innovation Programme of DG XIII (Telecommunications, Information Market and Exploitation of Research), with the aim of developing a pre-industrial prototype fixture specifically for carrying out punch and bulge testing for the mechanical characterisation of small material specimens. This specialist fixture is innovative (European Patent Application # 97830375.8) in that it incorporates the necessary components for monitoring of specimen out-of-plane deformation using advanced techniques in optical metrology, namely, Digital Speckle Pattern Interferometry (DSPI) and White Light Interferometry (Figure 5.11). The fixture is compact and design to be mountable on a standard mechanical testing machine. Using such a device, set-up of a punch or bulge test is straightforward and the test procedure itself (including loading and data acquisition) is highly automated. The fixture and associated instrumentation is easily calibrated and the overall handling and operation of the test system does not require highly skilled operators. The test fixture overcomes serious technical difficulties associated with current Punch and Bulge testing methods. In particular, the device allows effective quality control of the testing procedure, helping to identify clearly undesirable experimental artefacts such as excessive end-effects, non-ideal clamping, errors in load application and inaccurate displacement/strain measurements. It also provides more comprehensive, full-field data regarding specimen behaviour rather than the simple load-deflection data obtained from existing test methods. Discussions are currently taking place with an established manufacturer of mechanical test equipment with the intention of eventual commercialisation of the device.

During the testing campaigns associated to these projects, it is expected to give access to the facility to more than 50 European researchers from universities and industry, including also several Young researchers.

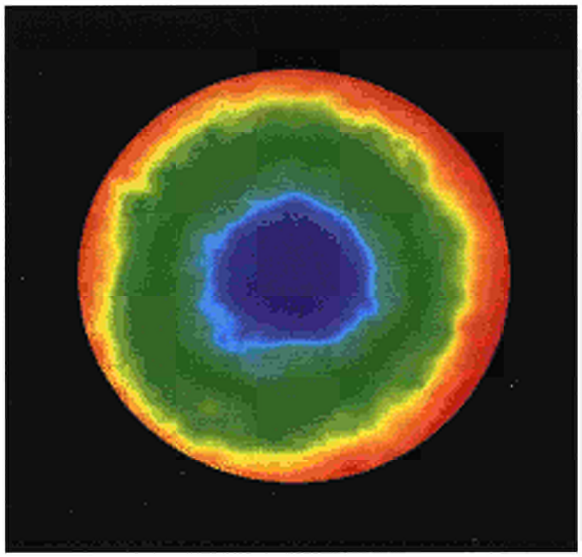


Figure 5.11: Deformation map of 8mm diameter disk specimen measured on-line using DSPI during a Small Punch test.

44 ELSA Large-scale facility (LSF)

ISIS contact: A. Pinto

The ELSA (European Laboratory for Structural Assessment) Laboratory is a European Large-scale Facility used for earthquake engineering studies. In the LSF project, financed by the TMR programme, the major task of ELSA is to enable researchers and industry to perform tests on large-scale structures and contribute to the training of European researchers.

45 ELSA reaction wall facility (ECOTEST 2)

ISIS contact: G. Verzeletti

ELSA is also a member of the European testing facilities in earthquake engineering (ECOEST2 consortium), which includes, in addition to the ELSA reaction-wall, five European shaking-table laboratories. To co-ordinate these activities the ECOEST2 management panel meets regularly and the ECOEST2 Users panel, including also external experts in field, selects and controls the projects to be developed in the facilities.

Three out of seven projects received for ELSA were selected according to their scientific content and available funds. These deal with safety of constructions, namely:

- *the assessment and retrofitting of existing buildings designed and constructed without appropriate seismic resisting characteristics;*
- *the design and detailing of shear-walls with non-rectangular cross-section;*
- *the innovative design methods for structures under seismic loads. Three corresponding large/full-scale tests will be performed during 1999 (Figure 5.12).*

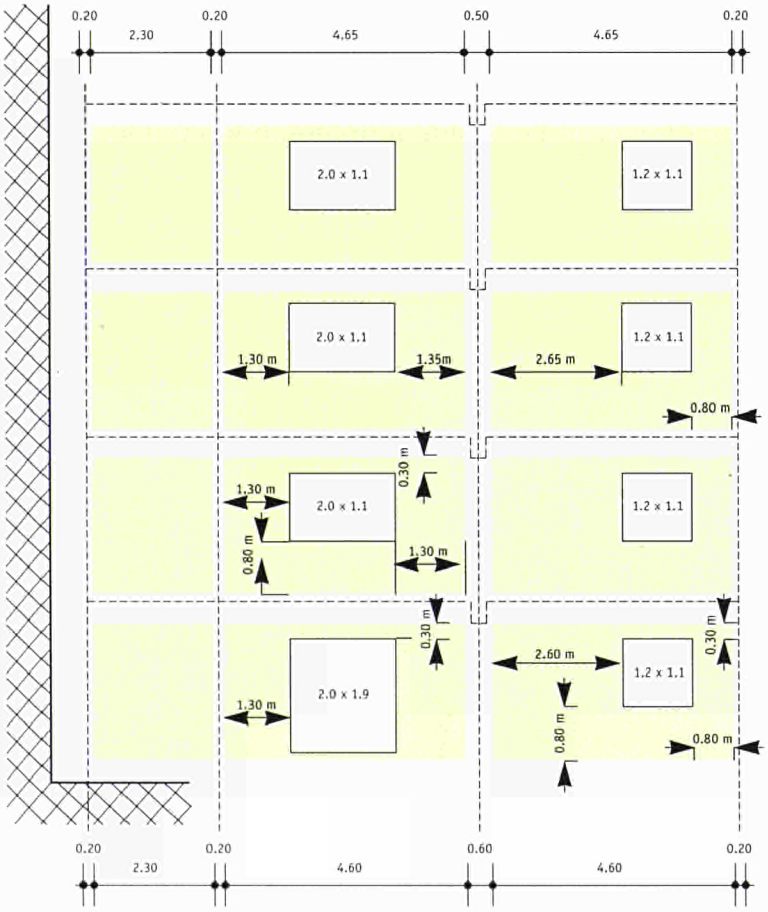


Figure 5.12: Full-scale test model of the reinforced concrete frame to be tested at ELSA (assessment, strengthening and repair).

46 Advanced Structural Dynamic Experimental Facilities (ASDEF)

ISIS contact: M. Géradin

ISIS' large reaction wall, ELSA, is one of the European Advanced Structural Dynamic Experimental Facilities. ASDEF provides young researchers from across the EU access to the full range on large scale dynamic facilities and enables them study seismic behaviour of buildings.

47 Innovative seismic design concept for new and existing structures (ICONS)

ISIS contact: A. Pinto

The ICONS research network, also financed under the TMR programme, deals with concepts and subjects in earthquake engineering, which should be developed further to convert Eurocode 8 into a truly state-of-the-art standard for the safe and economic design of earthquake resistant new structures and for the seismic upgrading of existing ones [5.10].
The research approach for ICONS combines analytical/numerical and experimental work. The former includes development and calibration of analytical models to represent the cyclic behaviour of the different structural materials and elements, parametric numerical analyses of complete structures and development of innovative design methods. The experimental work facilitates calibration of models and assists in the assessment of proportioning and detailing rules for the different structural sub-assemblages as well and in the assessment of existing and new design methods.

ISIS, in addition to the general co-ordination of the network, is developing analytical tools for the seismic assessment/retrofitting of existing structures and for composite structures. Furthermore, it participates in the design and setup of the experimental work at ELSA. Very positive and encouraging statements are included in the assessment report resulting from the mid-term review process concluded last December.
In short, under the TMR programme, ISIS is also providing a significant contribution to training of Young researchers in earthquake/structural engineering, dealing with advanced approaches and methods which are expected to contribute to the up-dating of the European seismic design code (Eurocode 8).

[5.10] Pinto A.V. Introduction to the European Research Projects in Support of Eurocode 8. In *Proceedings of the 11th European Conference on Earthquake Engineering*. Balkema, Rotterdam, ISBN 90 5410 982 3, 1998.

48 Anchorage in normal and high performance concrete subjected to medium and high strain-rates (ANCHR)

ISIS contact: G. Solomos

Anchorage consists of a metallic element, rebar or anchor, and the concrete base material, where the metallic element is embedded with or without a bonding agent. Improving the base material mechanical characteristics and enhancing our understanding of the anchorage response, principally to dynamic loads, are the two key issues of the work. New materials design of high performance concrete, materials modelling (including the strain rate dependence of the stress-strain curve of concrete and its softening branch) and numerical simulation tools are pursued.
An extensive experimental programme, mainly carried out at ISIS, is intended to support all theoretical developments. Central in this high strain-rate testing activity, is the employment of various Hopkinson bar techniques, particularly suited for precision pullout tests.
Most of the work in 1998 has been aimed at designing the specimens of normal and high performance concrete (NC, HPC), which include: plain concrete cubic specimens, rebar anchorages (cast-in-place and post-installed) and anchors. Several tests have been performed at the Large Dynamic Test Facility (LDTF) at ISIS confirming the suitability and the performance of the specimens as designed.

49 Advanced methods for assessing the seismic vulnerability of existing motorway bridges (VAB)

ISIS contact: A. Pinto

A leading motivation behind the VAB project is the evidence brought about by recent seismic events all over the world that bridge structures are particularly sensitive to the effects of earthquakes. A significant example in Europe is the severe bridge damage observed after the 1976 Friuli earthquake. Furthermore, the evidence from earthquakes in California (1994) and Japan (1995) definitely points to long bridges and highway and railway viaducts as the potentially weakest elements in transportation systems.
Insufficient consideration for seismic risk in bridge design has resulted in inadequate detailing of confining steel and insufficient shear reinforcement in the bridge piers, insufficient seat length of bearings, and inadequate design of the bridge abutments. Furthermore, there are many open questions concerning the ductile behaviour of large bridge piers, in particular those with rectangular hollow cross-section commonly used in Europe.
ISIS is participating in the project as the major partner for the testing activity. Four large-scale models of typical bridge piers with different span ratios will be tested at the ELSA laboratory using non-linear substructuring techniques.
The work in 1998 concentrated on the preliminary analyses of the bridge prototype for the definition of the test models and on the development of the testing methods including the non-linear substructuring to be used in the on-line control of the experiments.

50 Further developments in dynamic control of earthquake engineering facilities (FUDIDCOEEF)

ISIS contact: G. Magonette

The JRC has developed a system capable of performing high-speed continuous pseudo-dynamic tests, facilitating measurement of earthquake response of structures with velocity-dependent devices. In this structural dynamics testing system the critical section of the structure is tested by reproducing the forces and displacements imposed on it by the surrounding structure, which is modelled numerically.
This research has been based on the minimal control synthesis algorithm developed at the University of Bristol. The first phase has been to investigate how to combine the accurate feedback of displacement signals at low frequencies with the accurate feedback of acceleration signals at high frequencies, to produce a satisfactory correction signal in the 0-50Hz range. A successive development has been a basic analysis of the kinematic and dynamic aspects of actuator performance. A new electronic hardware based on multiprocessor architecture has been designed and realised to implement the integration algorithm and the new control software.

51 Active control in Civil Engineering (ACE)

ISIS contact: V. Renda

Cable-supported structures and particularly long-span suspension or cable-stayed bridges are among the most important engineering structures of the second half of this century. Today it can be claimed that cable-stayed bridges have entered a golden age.

Considerable progress has been made in bridge dynamics during the last 10 to 20 years. In several cases the exciting mechanisms have been identified, and engineers and scientists have progressively got a better understanding of the problems. A frequent reason for cable vibrations appears to wind in combination with rain: the so-called rain-wind induced vibrations. But also wind and traffic loads may give parametric excitation of the cables resulting in unacceptable oscillations.

To prevent such vibrations, passive measures like cross-ties interconnecting the stay cables or dampers installation at the bridge deck have been widely used. But some problems have occurred with these systems. The initial tension of the cross-ties must be selected with care in order to avoid detensioning and shock effects in the cable system. Viscous dampers located near the cable anchorage at bridge deck have a limited damping effect, in particular in the case of parametric excitation.

For long cables, the active damping strategy may be applied. The aim of the active control system is to upgrade the damping of the structure and consequently to mitigate the induced vibration of the stay cables. The methodology considered here is based on an active tendon consisting of an actuator collocated with a force sensor. The active damping is based on the control of the displacement of the cable anchor point.

The specific objectives of the testing campaign to be performed at ISIS are:

- *to improve the understanding of induced vibrations (the mock-up will be subjected to forcing functions);*
- *to validate the numerical tools for prediction of dynamic behavior of cables;*
- *to verify the capability of the active system to mitigate the effects of induced vibrations;*
- *to evaluate in detail the performances and the reliability of the whole implementation.*

52 Towards European integration in seismic design and upgrading of building structures (EUROQUAKE)

ISIS contact: A. Anthoine

The essential thrust of the project is an improvement in seismic design procedures and strengthening/repair techniques for masonry infilled reinforced concrete frames. The purpose of the research programme is:

- *to improve the current understanding of the non-linear seismic response of such structures,*
- *to develop and validate numerical models capable of accurately simulating their non-linear seismic response,*
- *to develop and validate strengthening and repair techniques,*
- *to transfer research results into practical design recommendations.*

The work performed at ELSA consisted in testing full-scale masonry infills with and without reinforcement, the scope being to obtain basic data on the response of such infills when the surrounding frame is submitted to prescribed lateral displacements of increasing amplitude (simulating an earthquake loading). In each test, two masonry panels, one plain and the other reinforced, were tested in parallel. The reinforcement was provided by polymeric grids inserted in the horizontal mortar joints and in the plaster of both external faces of the panel. Two infill layouts, one without opening, the other with non-symmetrical openings (a door and a window) have been tested successively. The tests evidenced the improved response of the reinforced infills (higher strength and enhanced ductility).

[5.11] Magonette G., Pegon P., Molina F.J., Buchet P. Development of Fast Continuous Pseudodynamic Substructuring Tests. *Second World Conference on Structural Control.*, Kyoto, Japan, 28 June - 1 July 1998.

Transport safety

editor: P.C. Cacciabue

Technological development and needs of the society have strongly enhanced the transport systems. The vast amount of work and persons involved in the transport domain and the impact that the transport has in the social life of modern society, make the question of safety (together with sustainability) the most crucial goal of future development of transport. The safety levels reached today are very high. The low rates of accidental events resulting in casualties and environmental damages are generally acceptable both to the public and to the regulatory bodies. However, these rates have reached a plateau value (as far as civil aviation is concerned), which needs to be carefully examined. Indeed, if these records are not improved further, the above mentioned augmented speed and capacity of the transport means and the increase of traffic density would result in unacceptable consequences, with much larger environmental and social impacts, due to the increased overall number of accidents per year.

For these reasons the safety issue of the future transport systems needs to be tackled and fulfilled both at regulatory and technical levels. Moreover, as this subject spreads throughout the whole of Europe (and the world), the question of safety becomes a trans-national one, demanding the use of internationally accepted means and methods.

The Fifth Framework Programme gives particular attention to structural crash safety of vehicles and to the Co-ordination Centre for Aircraft Incident Reporting (ECCAIRS). But ISIS will continue to perform research and services in areas as aviation safety studies, human factors research, maritime technologies and Arctic Sea transport by the competitive support to the General Direction VII (Transport), to the industrial world and to other European research institutions, both at national and international level.

European Co-ordination Centre for mandatory Aircraft Incident Reporting Systems (ECCAIRS)

author: W. Post

The ECCAIRS reporting system, which is maintained, supported and made available to EU civil aviation authorities, is used to collect aviation incident information from EU member states. Its network allows the authorities to exchange information amongst themselves and to contribute to the EU information system in the ECCAIRS central office. The project's objective is to have all EU member states participating actively in the ECCAIRS network by the end of the fifth framework programme. From the central office, data and derived information is disseminated to the national aviation authorities and other authorised organisations.

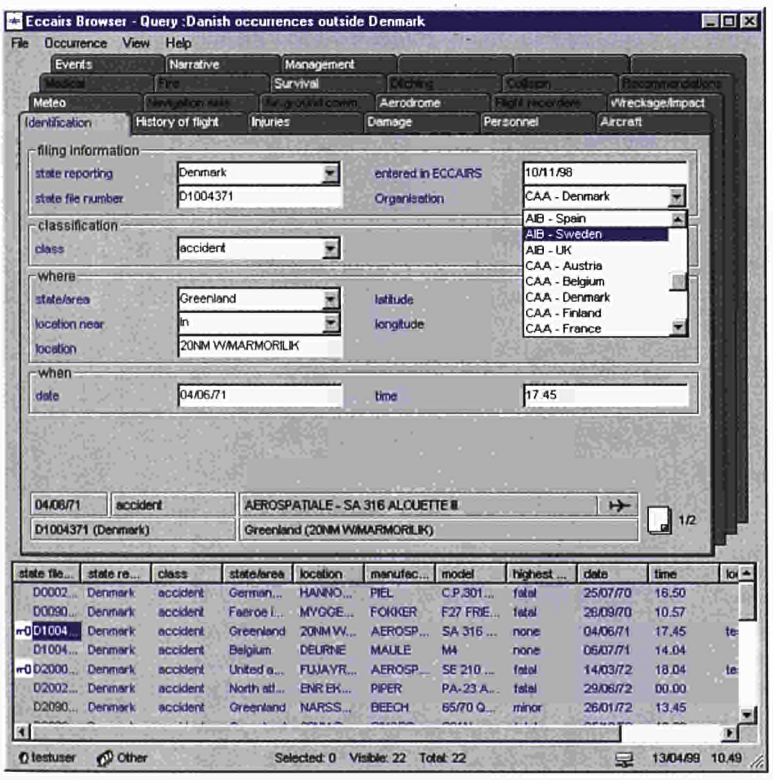


Figure 6.1: ECCAIRS'query on the integrated occurrence database showing how accident/ incident data can be entered. The lines below it are an example of the query results with the accidents reported by Denmark that occurred outside its country.

The ECCAIRS project has designed and implemented the tools and the network which are at the basis of the proposal (prepared by DGVII - Transport) for an EU Council Directive: "Establishing a co-ordinated system of national mandatory occurrence reporting schemes in civil aviation".
This proposal is based on the conviction that the establishment at Community level of a mandatory reporting system is feasible and that a suitable tool (ECCAIRS) has already been developed. This tool can work as a centralised system for the Member States which do not want to develop their own data - base or as a decentralised one to facilitate the exchange of information with those who want to have one.
This Directive should become active in the period of the fifth framework programme. To support the upcoming legislation two strategies have been defined:

- Provide an IT based solution (reporting system) for EU member states with which they can collect the required information in a standardised way.

- Implement a network, which integrates the data collected in the individual Member States and co-ordinates the available resources at European level to improve cost efficiency and share knowledge.

In 1998 the first production release of the European Co-ordination Centre for Mandatory Aircraft Incident Reporting Systems software has been distributed to twenty aviation authorities in Europe and other countries. This software allows the authority to collect civil aviation incidents and accidents following an internationally well-accepted standard (ICAO-ADREP'87). Furthermore, the contents of these national information systems can be sent electronically to the central office of ECCAIRS at ISIS, to peer organisations in other EU countries and potentially also to ICAO (International Civil Aviation Organisations, the UN authority for civil aviation) [6.1]. An example of the browser application is shown in Figure 6.1.
Contacts have been established with most of the EU authorities interested in the product. These organisations will form the main nodes of the ECCAIRS network, to be completed in the coming years; the present situation is sketched in Figure 6.2. The

References

[6.1] Post W. ECCAIRS Project Progress Report 4.1. *Technical Note No. I.98.208*, 1998.

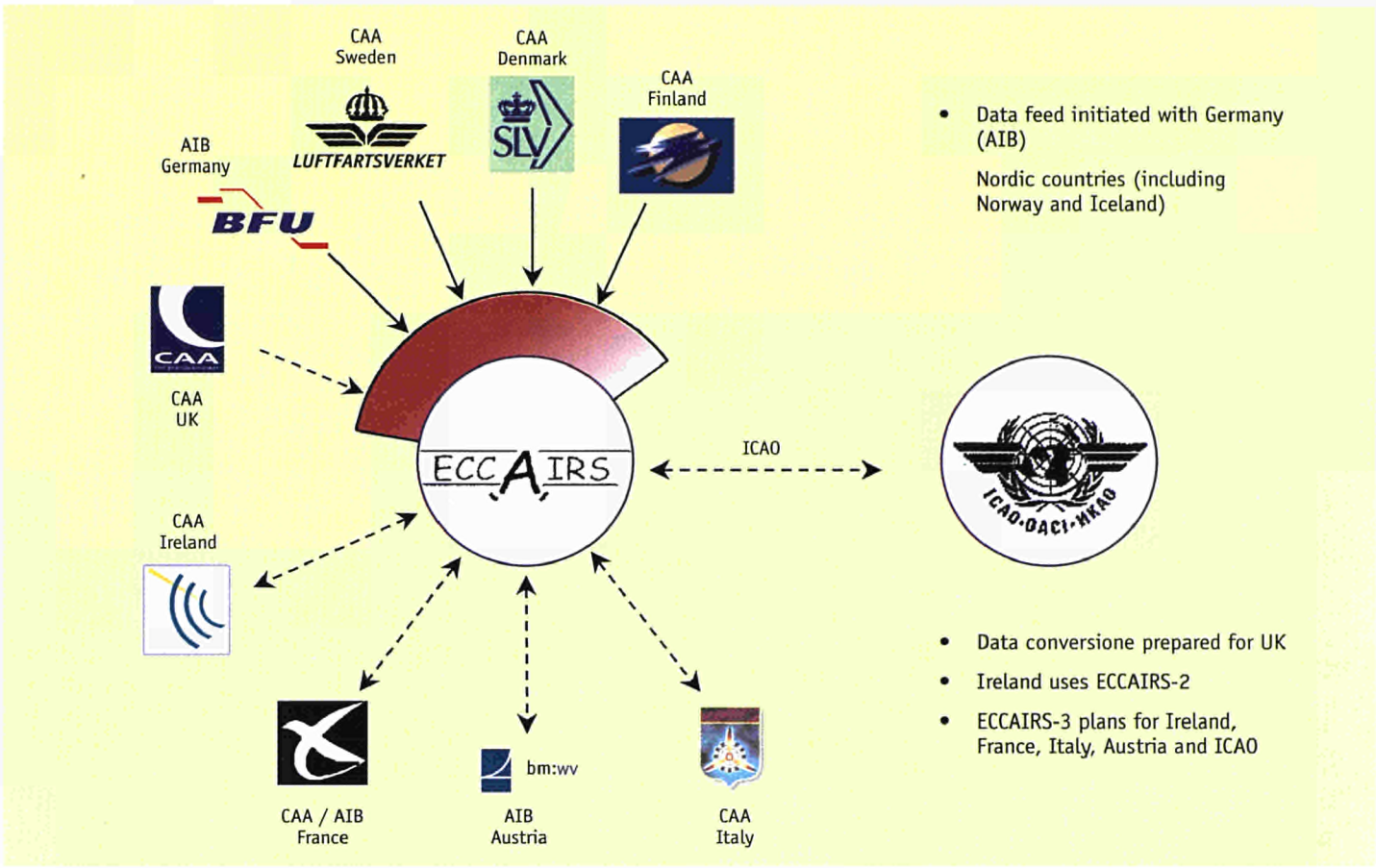


Figure 6.2: Present situation of the ECCAIRS network with national Civil Aviation Authorities (CAA).

directive proposed in 1998 by DG VII will force Member States to start collecting aviation incidents in an automated way; this directive specifies ECCAIRS as a valid support tool. At the end of 1998, the Danish Civil Aviation Authority (CAA) became the first authority to formally declare that it would apply ECCAIRS as its future incident reporting system starting in January 1999.
During 1998 resources for the period 1999-2002 have been assured by winning a call for tender by DG VII (competitive support to the Commission) and via the introduction of ECCAIRS in the Fifth Framework Programme of the European Commission; see http://eccairs-www.jrc.it

Human factors training

authors: M. Bacchi, M. Pedrali

Crew Resource Management for ALITALIA

The CRM (Crew Resource Management) is a training course dedicated to develop an understanding and awareness of the human factors (HF) issues amongst airliner pilots. This type of training became compulsory in Europe in 1998 and is already widely spread within many Airline companies. The CRM course developed by ISIS has been exploited for the national Italian carrier, Alitalia. In 1998 a final analysis of the data collected by the Flight Management Attitudes Questionnaire (FMAQ) was carried out. The "open questions" related to the views of Alitalia pilots on flight operations and training were studied.

[6.2] Bacchi M., Ponzio P. FMAQ-Open Questions in the Alitalia Attitude Survey – Recommendations on how to improve Alitalia Training. *JRC/ISIS TN I.98.138*, 1998.

[6.3] Bacchi, M., Ponzio P. FMAQ-Open Questions in the Alitalia Attitude Survey – Recommendations on how to improve Alitalia Flight Operations. *JRC/ISIS TN I.98.249*, 1998.

This final analysis will further contribute in refining the CRM course and make it more tailored to the Company needs and policies [6.2, 6.3].

Crew Resource Management for MERIDIANA

The contract with the Italian airline Meridiana (IG) focused on the safety culture of the Company and the development of material and tools for supporting the instructors during Line Oriented Flight Training (LOFT) sessions.
The safety culture existing in Meridiana was studied by applying the FMAQ questionnaire, as had already been done with the Alitalia pilots'. The findings of this study have been very useful in defining the content of a specific CRM training that will be developed targeted on the airline's needs. LOFT was supported by devising a grid for the evaluation of important HF indicators to be considered during the LOFT simulator sessions. This grid and the associated indicators will be the object of further test in real simulator sessions before completing the project with the development of a supporting manual dedicated to the flight instructors. Two other actions were carried out in the framework of the Meridiana contract:

- A general evaluation of compliance of the existing activities within Meridiana versus the new standards required by the Joint Aviation Authorities.
- A Flight Instructor Course for evaluating attitudes of flight instructors versus the company policies and standards and for developing the necessary non-technical (HF) skills needed for interacting with (pilots) trainees.

EAAP-ISIS Collaboration

In collaboration with the European Association for Aviation Psychology, ISIS is developing European training standards in the domain of Aviation and has organised three courses that will be held in the spring and autumn 1999 on Human Error Management, Counselling, and Accident Investigation.

Air Europe-ISIS Collaboration

ISIS collaborated with Air Europe in developing practical tools for implementing the briefing and de-briefing of HF issues during training in the simulators. This activity, although financially very small, contributes to the development of basic know how of the Institute. In the future further field studies are foreseen.

Human factors assessment of the Italian railway system

authors: P.C. Cacciabue, P. Ponzio

The technical study of issues related to human factors (HF) and train drivers of the Italian Railway System (Ferrovie dello Stato, FS) has been carried out in collaboration with the English consultant Arthur D. Little (ADL). The study has followed a classical approach that is based on the contribution of three major lines of analysis. The theoretical and methodological approach coupled with extensive field analyses and interviews with train drivers, instructors, managers and FS experts; and lastly the study of written guides and procedures and of accident statistics and retrospective studies.
The study led to the identification of 8 major areas of intervention and a number of recommendations aiming at improving both climate and quality of performance of train drivers. Particular attention was dedicated to the introduction of extensive automation of the railway system; the approach used is schematically shown in Figure 6.3.

53 *Human factors in Aircraft Dispatch And Maintenance Safety (ADAMS)*

ISIS contact: M. Bacchi

ADAMS is the study and design of an integrated human factors (HF) safety system for aircraft maintenance and dispatch. During 1998, ISIS was involved in two main activities: methodologies for accident/incidents analysis and evaluation of the effectiveness of Human Factors Training Courses.
1. Methodologies for accidents/incidents analysis where ISIS research activities aimed at evaluating the ADAMS Reporting Form; ameliorating the Form and Taxonomy and developing the end-user manual. To reach these objectives, the ADAMS Taxonomy was first "translated" into a paper tool-form, then a draft end-user manual was developed. The Reporting Form was then tested using two different methodologies and according to the results obtained by the evaluation, the final version of the Reporting Form and the final end-user manual were developed.
2. Evaluation of the effectiveness of Human Factors Training Courses: ISIS' activity focused on the development and evaluation of a new and enhanced tool to support maintenance organisations in assessing the effectiveness of their HF training courses. The ADAMS Aircraft Maintenance Attitudes Survey (AMAS) questionnaire was developed and tested. This

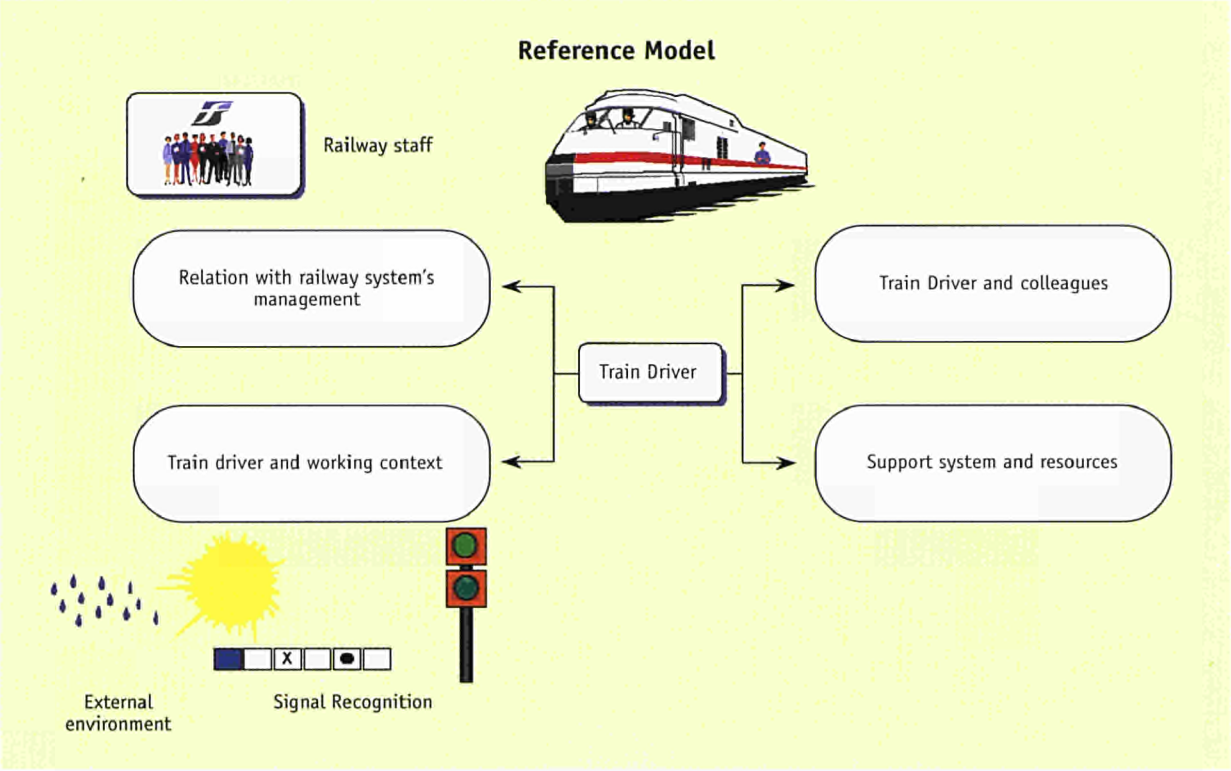


Figure 6.3: Reference scheme of train driver and his/hers working environment. This model represents the main factors influencing the train driver's activity including the interaction with the working environment (socio-technical context), colleagues, control instrumentation and relationship with the railway system's management.

questionnaire is mainly directed to front line maintenance operators (mechanics, technicians and team supervisors), and measures attitudes toward teamwork (communication and co-ordination, sharing command responsibility, recognition of stressors effects), and the preferred style in problem solving and decision making. According to the results obtained, in its current format, the questionnaire can be successfully used to identify HF training needs (areas in need of amelioration) and to evaluate the relevance and effectiveness of HF training courses (if applied before and after a training course).

54 Air transport safety by risk evaluation and cost-benefit analysis (DESIRE)

ISIS contacts: M. Pedrali, P.C. Cacciabue

The stand point of DESIRE is that Systematic Safety assessment based on quantification and data may not be utilised for further reducing safety to 10^{-6} accident probability. A more crucial application of Systematic Safety analysis is in identifying areas, issues and factors that affect safety and may need to be changed, or looked into with more care (independently of the probability value). The objective of DESIRE is to develop a quantitative risk assessment model of air transport safety allowing cost-benefit analysis of safety measures and an approach to air transport safety improvement.

One of the primary conditions to transport by air is safety. The number of accidents, as perceived by the travelling public, determines safety. To prevent an increase in the number of accidents, the improvement in relative safety (the likelihood of an accident per flight) must keep pace with the growth in traffic volumes. However, another condition to transport by air is affordability. Safety improvement measures can not be carried out without due consideration of the associated cost issues. Hence, the costs of safety measures must be balanced with the need to improve relative safety. Other crucial issues will concern whether particular safety measures are likely to be cost-effective, which safety measures should be given priority over others, whether or not the intended safety measures can be expected to be sufficient to meet the desired overall level of safety.

The purpose of the proposed project is to develop a method which will allow manufacturers, operators and regulators to answer these questions and thus to

support them in achieving an adequately large improvement in relative safety.
In the first year of the project, the development of a taxonomy of causal and contributing factors, and a taxonomy of cost factors in aviation accidents/incidents was carried out. While the former will enable to establish the frequency of occurrence of these events, the latter will allow cost benefit analysis. Based on the causal factor and cost information a causal model for risk assessment will be built for which the user requirements and functional specification have been defined.

55 Human factors distance training on the Internet (SafetyNet)

ISIS contacts: M. Pedrali, P.C. Cacciabue

The aims of SafetyNet were to demonstrate a scaleable Internet HF training subscription service based on the "virtual classroom" training modality; and to establish this as a base line for the development of a commercial service to safety and time-critical domains (such as civil aviation, maritime operations, rail systems, process plants, and medical systems).
The project came to an end beforehand both because of weakness of the business case for delivering HF training via the Internet, and the costs demanded for the equipment. Indeed, the SafetyNet project would have integrated and applied the leading edge technologies of video conferencing, advanced multi-media, and distributed simulation to create the virtual classroom [6.4]. However, there is value in capturing the main experiences and lessons learnt in the project, from both a technical and business point of view, for the benefit of the wider community.

Accident analysis and human factors data

authors: P.C. Cacciabue, A. Perassi

Following the research actions oriented to the accident analysis, safety assessment and human behaviour studies [6.5-6.10], ISIS has been involved in the development of the new Accident Classification scheme (ADREP-2000) proposed by the International Civil Aviation Organisation (ICAO).
This classification scheme has been applied for a first estimate of applicability to the Gottröra accident, occurred in 1991 in the Stockholm airport area. This preliminary study sowed that, while the system is applicable, further tests were necessary in order to fully assess advantages and open issues associated with ADREP-2000 [6.11].
To reach this further goal, especially in relation to HF, an extended comparison exercise has been initiated within the project ECCAIRS. This exercise also aims at evaluating the user friendliness and complexity of the new classification, so as to ascertain whether the inclusion of detailed HF items leads to a clearer, or indeed a fuzzier, representation of the accident causes and evolution. The findings of nine real accidents will be classified according to the old and the new classification scheme by two ISIS

[6.4] Pedrali M. M.I.S.S.: Towards a Multimedia/Multi-layer Integrated Storage System of Human Error Causes. In *the Aviation, Proceedings of HCI-Aero '98, International Conference on Human-Computer Interaction in Aeronautics*, pp. 43-48, May 27-29 Montreal, 1998.
[6.5] Cacciabue P.C. Modelling and Simulation of Human Behaviour. In *System Control*. Springer-Verlag, London, UK, 1998.
[6.6] Cacciabue P.C. Modelling and Simulation of Human Behaviour. In *Process Control: Needs, Perspectives and Applications. 2nd European Conference on Engineering Psychology and Cognitive Ergonomics*. Oxford, UK, October, 28-29, 1998.
[6.7] Carpignano A., Piccini M., Cacciabue P.C. Human Reliability for the Safety Assessment of a Thermoelectric Power Plant. *European Safety and Reliability Conference* 1998, Trondheim, Norway - June 17-19, 1998.
[6.8] Cacciabue P.C., Hollnagel, E. Human Factors Methods for Safety Assessment in Highly Automated Environments: Task Analysis, Modelling, and Data. In A. Mosleh and R.A. Bari (Eds), *Proceedings of PSAM 4 - International Conference on Probabilistic Safety Assessment and Management*. New York, 13-18 September, 1998, Springer-Verlag London, UK.
[6.9] Cacciabue P.C., Carpignano A., Piccini M. Human factors assessment for highly automated systems: a case study of a power plant. In A. Mosleh and R.A. Bari (Eds), *Proceedings of PSAM 4 - International Conference on Probabilistic Safety Assessment and Management*. New York, 13-18 September, 1998, Springer-Verlag London, UK.
[6.10] Bellorini A., Cacciabue P.C, Nanetti N. Ambiguity and Problems of Communication in Air Traffic Control. *Ninth European Conference on Cognitive Ergonomics, ECCE-9*. The University of Limerick, Ireland, August 24-26, 1998.
[6.11] Perassi A., Cacciabue P.C. Human Factors Insight in Databases of Aviation Accidents: Comparing past and present Classification Schemes. *17th European Annual Conference on Human Decision Making and Manual Control*. Valenciennes, France - December 14-16, 1998.

teams and one of ICAO specialists. The classification exercise by the three teams is presently in an advanced state and the actual comparison will be carried out during 1999.

Collaboration with Italian universities and research centres

author: P.C. Cacciabue

In the last year an extensive research programme has been carried out in collaboration with the Aerospace Department of the Politecnico di Milano. This collaboration aims at developing models and methods for Human Machine Interaction studies in the civil aviation domain. [6.12, 6.13].

The research carried out at ISIS together with the Aerospace Department and Department of Energy Systems of the Politecnico di Torino focuses on human reliability methods, accident investigation methods and related data collection and analysis [6.14, 6.15].

The collaboration with the Department of Psychology of the University of Padova has been focused on the issue of HF analysis within the aircraft maintenance domain [6.16].
Within the context of the Italian HF Steering Committee, ISIS has been involved together with the Italian Aerospace Research Centre - CIRA and Meridiana in the design of a voluntary reporting program such as the Aviation Safety Reporting System (ASRS) developed by NASA. This programme collects confidential reports from airlines' personnel (pilots, flight attendants, and mechanics) that were involved in, or observed, an incident or situation in which aviation safety was compromised. ISIS contributes with the design of the forms to be used in the reporting stage.

Vehicle structural safety

author: C. Albertini

The increasing severity of European motor vehicle and road safety standards and constraints due the European environment protection policies pose to the vehicle industry the challenging and critical problem of designing vehicle bodies weighing less but having improved crashworthiness performance.

Thus, European Safety Authorities and vehicle industry need the support of advanced research in the field of impact response processes of vehicles and road safety structures. In this sense the ISIS's Large Dynamic Test Facility (LDTF, Figure 6.4) represents a unique integrated environment for the mentioned advanced research aimed to enhance vehicle and road barriers crashworthiness. Work in 1998 was centred on the following activities:

- Development of precision crash testing methodologies of passive safety vehicle structures and of road safety barriers (Figure 6.5). These gave reference measurement for checking the accuracy of crash computer simulation and the efficiency of passive safety structures. The development of these precision crash testing techniques is partly supported by DG III (Industry) because of their potentiality as less expensive alternative to the actual standard tests, especially with regards to the standard tests of large vehicles and barriers. Industries (such as Renault), national transport safety laboratories (such as the French INRETS) and the European Safety Standard Committee (CEN) are involved and actively take part in the projects.

- Support of industry for the characterisation under impact loading of new materials for crashworthy light-weight vehicle body structures, such as high strength steels and high strength aluminium alloys (e.g. Cockerill-Sambre, Hydro-aluminium).

[6.12] Fabbri M. Prospective Analysis Methods for Human Error Studies. Cognitive Simulation of an Aircraft Crew During the Approach to Landing Phase. *Graduation Thesis in Aeronautical Engineering* (in Italian), Politecnico di Milano, Italy, 1998.

[6.13] Barbieri A., Vallana, S. Wind-shear in Flight Safety. Development of an Integrated Crew-Aircraft-Environment Simulation. *Graduation Thesis in Aeronautical Engineering* (in Italian), Politecnico di Milano, Italy, 1998.

[6.14] Piccini M. Human Reliability for highly automated systems: a case study of a thermo-electrical plant. *Graduation Thesis in Nuclear Engineering* (in Italian), Politecnico di Torino, Italy, 1998.

[6.15] Perassi A. Human Factors in Flight Safety. *Graduation Thesis in Aeronautical Engineering* (in Italian), Politecnico di Torino, Italy, 1998.

[6.16] Baranzini D. Attitudes, Cognitive Styles and Communication Practices: A questionnaire for the aviation maintenance personnel. *Graduation Thesis in Psychology* (in Italian), Università di Padova, Italy, 1998.

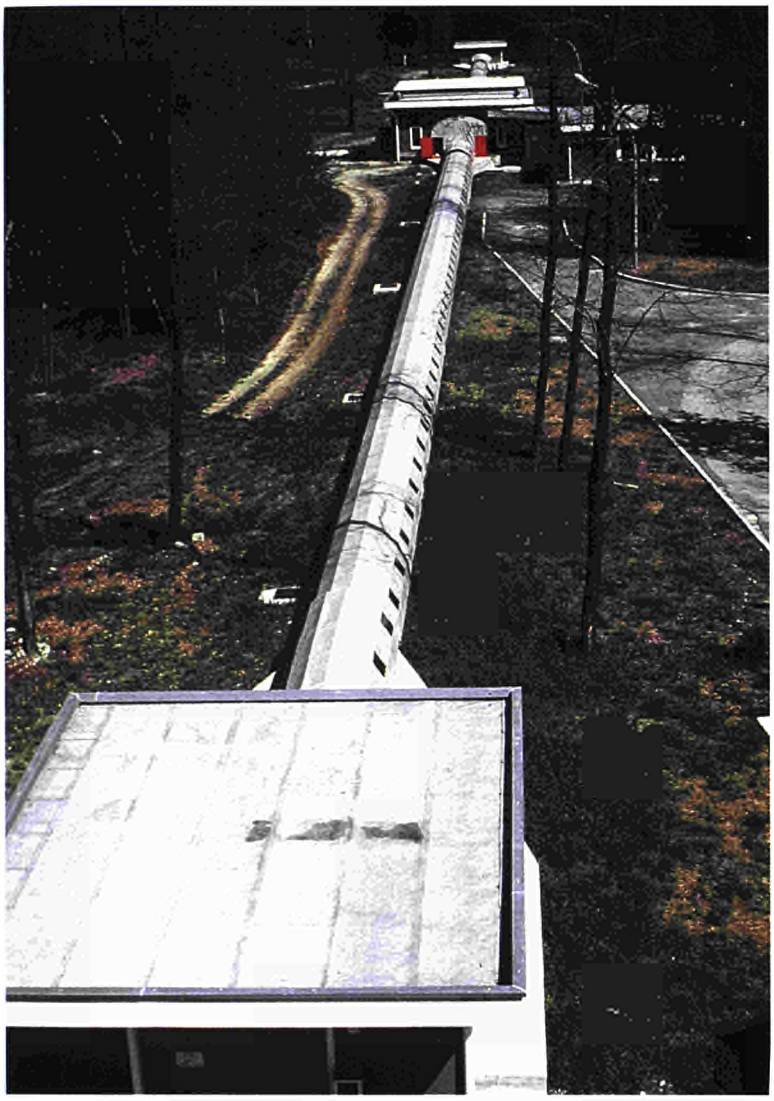


Figure 6.4: The Large Dynamic Test Facility (LDTF) at ISIS. This is the only method available for measuring the complete deformation/energy absorption history during a fast, dynamic event.

- Development of a new and improved crash energy absorption device based on high speed liquid jet formation, to be added to the present passive safety devices of the vehicles; this project is supported by DG XIII (Telecommunications, Information Market and Exploitation of Research) in JRC's Technology Transfer to Industry programme.

56 Integrated approach for fatigue design of low weight vehicle suspension components (FADIN)

ISIS contact: I. Papadopoulos

The release of every new design of an automotive component requires a long experimental durability assessment process. The FADIN project aims at time and cost reduction of this process by introducing reliable fatigue life predictions in the early design stage of one class of automotive components: suspension components. A Metal Fatigue Design Methodology is elaborated based on a mesoscopic scale approach for material behaviour, previously also developed at ISIS. The predictions of the new proposal are in excellent agreement with experimental results under multi-axial fatigue loads.

57 Remotely Operated Tanker Inspection System (ROTIS)

ISIS contact: F. Andritsos

The Remotely Operated Tanker Inspection System (ROTIS) project deals with the design, development and testing of a novel remote inspection system

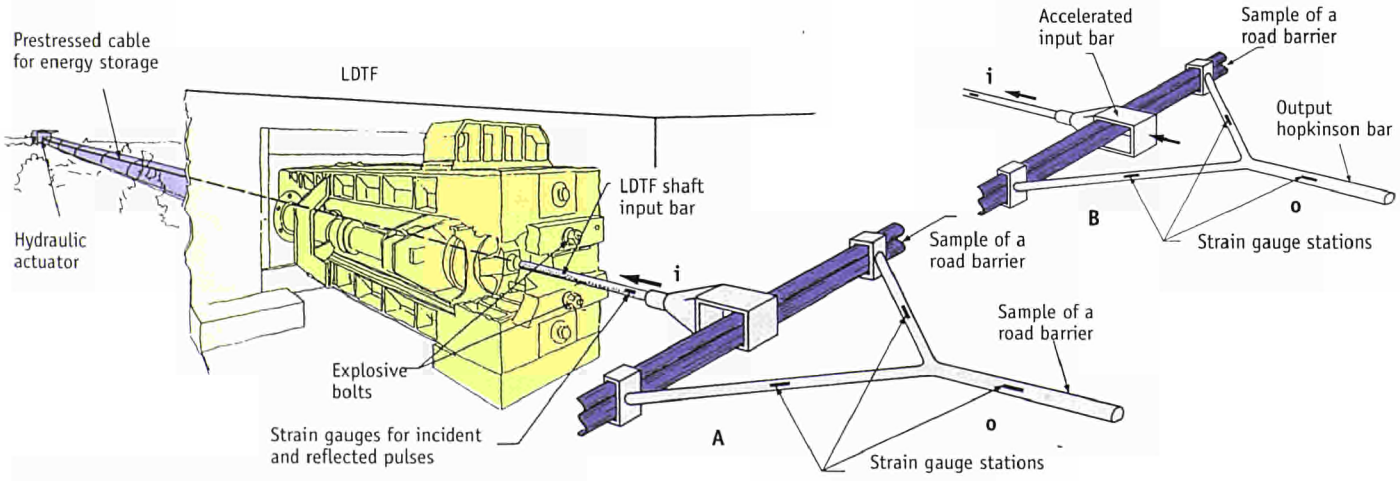


Figure 6.5: Three-point symmetrical Hopkinson bar bending test.
a) Impact-soft loading through the input bar; (b) impact-hard loading by the accelerated input bar. i: input bar, o: output bar.

(Figure 6.6). This system is based on a small Remotely Operated Vehicle (ROV) capable of navigating inside the ballast tanks of tankers and other cargo vessels, through the standard man-holes and openings to perform the close visual inspection and thickness gauging required by the classification societies during the periodic vessel inspections. ISIS had a fundamental role in creating the project and aggregating the consortium made up of seven European partners.

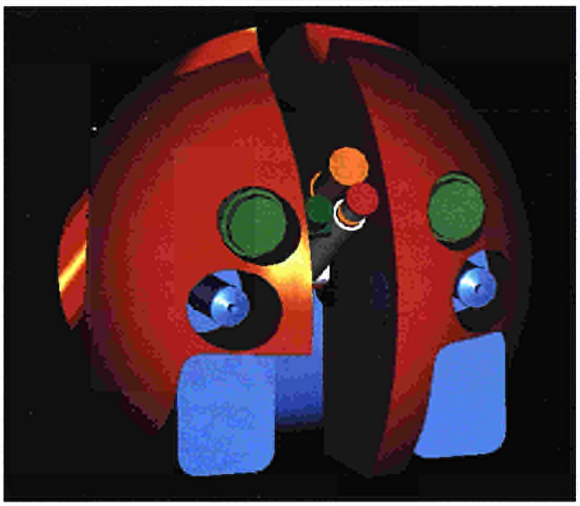


Figure 6.6: The Remotely Operated Tanker Inspection System - Remotely Operated Vehicle (ROTIS-ROV) prototype will be constructed. Left: the system will be tested in the ISIS test tank facility where a tanker ballast (right) mock-up will be constructed.

58 Arctic demonstration and exploratory voyage project (ARCDEV)

ISIS contact: S. Morris

In April/May 1998, ISIS participated in the Arctic voyage of the ARCtic Demonstration and Exploratory Voyage (ARCDEV) Project, a commercial/scientific

Figure 6.7: Finnish oil tanker Uikku being escorted through the difficult ice conditions of the Kara Sea (western Siberia) by the Russian nuclear-powered ice-breaker Rossiya.

Demonstration Project supported by DGVII (Transport) and DGXVII (Energy) aimed at demonstrating the feasibility of safe and economic transport of oil from western Siberia to the European market place (e.g. Rotterdam). The ice-strengthened Finnish oil tanker Uikku (17,000 tons) of the Neste fleet (Figure 6.7) was escorted through the ice-packs of the Kara and East Barents Seas by the ice-breaker Kapitan Dranitsyn of the Murmansk Shipping Company. The mission of collecting a cargo of gas condensate (a light oil) from the Yamal Peninsula and delivering it to the Rotterdam spot market was completed successfully. Teams of Russian and European scientists were based aboard the ice-breaker Kapitan Dranitsyn and jointly carried out tasks relating to ice surveillance and navigation, power requirements during ice-breaking operations including ramming of ice-ridges, and establishing ice stations on the ice-packs for measurements of ice thickness, topographic features of ice-ridges, and extracting core samples. An ISIS scientist participated in the voyage at the request of DGVII (Transport) as an EC observer on safety matters. This voyage highlighted a number of difficult technical challenges that need to be overcome in the harsh environment of the Russian Arctic in order to promote economic development.

59 Detection and assessment of seismic damage in reinforced concrete, transportation, primary tunnel linings (TUNNELLING)

ISIS contact: P. Negro

Many railways, road and metro-line tunnels are presently being built in seismic prone countries. The tunnels are often located under densely populated areas, and require very high standards of safety. There is an increasing awareness of the sensitivity of tunnel structures to seismic actions. However, damage to the tunnel structures is rather difficult to assess. The TUNNELLING project was launched with the aims

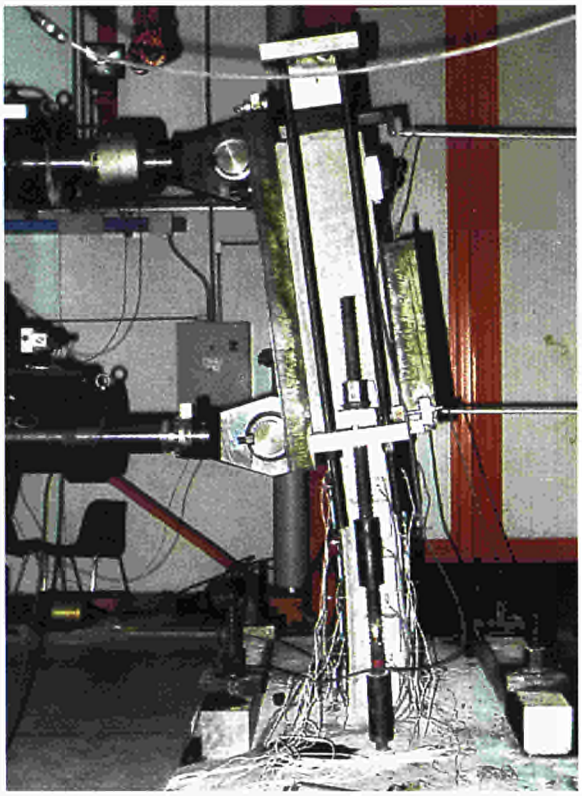


Figure 6.8: Experimental set-up for deformation in pure bending.

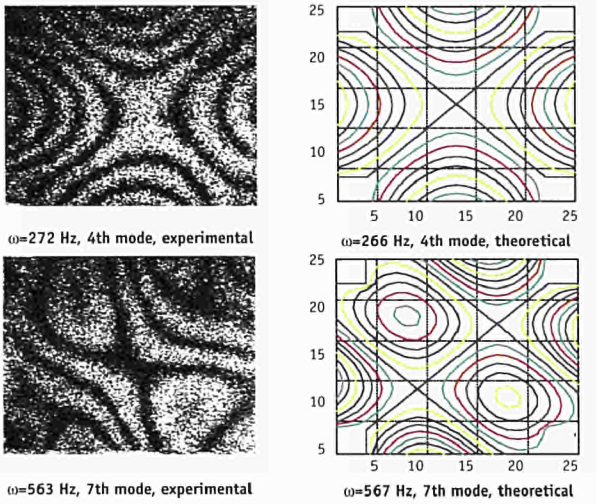


Figure 6.9: Two calculated and measured vibrational modes of a carbon reinforced composite panel of dimensions 0.45 x 0.45 m. The measurements on the panel were made using a pulsed out-of-plane ESPI system and show the interferograms prior to phase unwrapping which may be used to obtain the final displacements.

of developing a real-time system, based on the optical-fibre technology, to detect deformations in tunnels and to assess the remaining capacity of the lining to dissipate energy. The objectives of the research activity are to develop a suitable energy-based theory for structural failure, and to provide and assess an integrated package for real-time monitoring of the structural seismic vulnerability of the tunnel.

The role of ELSA (the European Laboratory for Structural Assessment at ISIS) in this project is to provide the necessary experiments for the validation of the failure theory and for the assessment of the optical-fibre integrated system.

A first series of tests has been conducted for the validation of the failure theory. A special set-up (Figure 6.8) was designed to apply pure bending (no experimental data seems to exist for this case). The size and strength of the specimen was kept reasonably small, having in mind the requirements of the real-time seismic tests for the assessment of the integrated package. A constant axial load was applied and maintained during the test by means of a pneumatic air-cushion system.

The resulting deformation measurements are being used in the calibration of the seismic stability module. In addition, the effect of shear in the cyclic non-linear behaviour is being studied by comparing the results of the two pairs of tests (with and without shear).

Advanced materials in transportation

author: R. Kenny

In this work so-called *smart materials*, in particular composite materials, are applied to transportation. Combined with the properties of composite materials, the capability to monitor a component or structure's performance offers several advantages. Improved design, such as reduced weight, is possible, as is improved maintenance and safety through early warning of damage or deterioration. A network of fibre optic sensors, which may be embedded into the material, performs monitoring. A demonstration unit has been constructed. It consists of a carbon reinforced composite panel embedded within a network of fibre optic strain sensors composed of 20 fibre Bragg gratings. An opto-electronic demodulation unit connects to the network and sends data to a PC for processing. A program uses the measured data with a Finite Element model of the panel to determine deformations and to locate damage. Figure 6.9 shows two vibrational modes of the composite panel. The calculations were performed by Finite Element Analysis taking into account the material and lay-up parameters. The measurements on the panel were made using pulsed out-of-plane Electronic Speckle pattern Interferometry (ESPI), a technique which allows full-field dynamic measurements to be made. This work has led to collaboration with a European helicopter manufacturer to study composite rotor blades using embedded and attached fibre optic sensors. It includes mechanical, fatigue and wind-tunnel testing.

Nuclear reactor safety

editor: H.A. Weisshäupl

In nuclear reactor safety there exists a great public concern regarding severe accidents with core melt-down, which has become a major issue since Three Mile Island and especially since Chernobyl, not least due to the cross-border aspect of the radiological consequences of such an accident. Nuclear safety will be an important consideration during the enlargement process.
ISIS provides direct support to DG XI (Environment, Nuclear Safety and Civil Protection) on various aspects of reactor safety, based on the competence stemming from many years of involvement in this field. Its research focuses on severe accidents, concentrating especially on key items with a high risk potential, and is well interconnected with the main activities of the Member States via shared-cost actions.
For the follow-up and assessment of future trends and new concepts, the studies on the accelerator driven systems were continued. The remote handling activities in the field of thermo-nuclear fusion led to important spin-offs.

Harmonisation and support to Commission Services in reactor safety

author: G. Cojazzi

ISIS supports DG XI (Environment, Nuclear Safety and Civil Protection) in the implementation of the two Council Resolutions (C128-75, C172/2-92) dealing with Reactor Safety and with the harmonisation of safety practices. In the future, the support will be extended to provide technical assistance in issues related to the enlargement process of the Union. In 1998, ISIS participated in the standing DG XI/C2 (Nuclear Plant Safety) advisory groups on reactor safety, namely the Reactor Safety Working Group and the Nuclear Regulators Working. ISIS contributed by participating in technical discussions and providing review of reports to some of the task forces and projects run by DG XI/C2 such as: the projects on aging, on Level 1 Probabilistic Safety Assessment (PSA), on safety critical software and on the task force on leak before break. Technical support has been also provided to DG XI/C2 in design-basis and severe accidents and PSA. All the Earthquake catalogues (EU, Central Europe, Former Soviet Union) funded by DG XI can now be exploited by means of a Geographic Information System (see also section on Natural Risks in Chapter 4 of this Annual Report) and are accessible on internet using a password [7.1]. ISIS participated in the activities of the Organisation for Economic Co-operation and Development (OECD) driven by the Committee for the Safety of Nuclear Installations (CSNI). Relevant working groups in areas such as risk assessment, thermal hydraulics, severe accidents have been followed to promote synergies and to avoid duplication with EC funded actions. A similar effort to promote synergies and to avoid duplication was also carried out for IAEA's activity. Participation in the European Safety, REliability and DAta (ESREDA) association was ensured.

In the field of harmonisation, an updated edition of the European Industry Reliability Data Bank, namely EIReDA 1998 has been prepared and made available to the technical reliability community. EIReDA results from a bilateral initiative between EdF and JRC and is co-authored by members of EdF and JRC-ISIS. It contains a compilation of estimates of reliability parameters, derived EdF plant data (failure rates and probability of failure on demand) and maintenance statistics. Extensive methodological appendixes are also included [7.2].

ISIS has contributed to technically supporting the Commission TACIS and PHARE Assistance/co-operation programmes with CIS (Community of Independent States) and CEEC (Central and Eastern European Countries), managed by the European Commission's SCR (Service Common Relex). JRC General Directorate is responsible for co-ordinating the support provided by the different institutes involved in this activity, namely ISIS, Institute for Advanced Materials (IAM) and Institute for Transuranium Elements (ITU). JRC-ADIN is also involved in issues related to radioprotection and waste. ISIS contribution focuses in thermal-hydraulics, design basis and beyond design basis accidents and severe accidents, risk assessment and management, structural dynamics. Support has been given to DG I/A (External Relations: Europe and the New Independent States) in designing safety industrial projects when drafting of contract Terms Of Reference (TOR), in selecting and evaluating project offers, in the follow-up and in the review of intermediate and final project reports. ISIS has given technical assistance to DG XI/C2 in the review and evaluation of PHARE and TACIS project reports related to Technical Support Organisations (TSO) regulatory assistance projects. DG XI/C2 also transmits to ISIS those reports that deal with regulatory authority projects for information. Reviews of intermediate and final TSO reports have been delivered in confidentiality by ISIS to DG XI/C2 on a regular basis and are grouped periodically in synthesis reports [7.3, 7.4].

References

[7.1] Peckham R.J., Boehner C., Eiselt B., Mattarelli M., Managing Earthquake Catalogues on GIS, Status Report-November 1998, Technical Note No. I.99.09, January 1999.

[7.2] Procaccia H., Arsenis S., Aufort P., Preface by Volta G. European Industry Reliability Data Bank, *EIReDA 1998*, Crete University Press, 1998.

[7.3] Cojazzi G., Valeri A. (Eds.), with contributions of: S. Contini, A.V. Jones, C. Kirchsteiger G. Solomos, H. Wider, A. Yerkess, Support to DG XI in Review of PHARE and TACIS "TSO Project" Reports, *Final Report, with appendixes A-F, EC-JRC-ISIS, DGXI-AA-96finrep.doc*, April, 1998.

[7.4] Cojazzi G., Valeri A. (Eds.), with contributions of: S. Contini, A.V. Jones, C. Kirchsteiger, G. Solomos, H. Wider, A. Yerkess, Support to DG XI in Review of PHARE and TACIS "TSO Project" Reports, *Final Report, Appendix G, EC-JRC-ISIS, Technical Note No. I.98.75*, April 1998.

Corium quenching and spreading in FARO

author: D.Magallon

FARO and KROTOS experiments aim at understanding the quenching behaviour of corium melt-water systems in order to evaluate the potential for debris cooling in case of severe accident in nuclear power plants. FARO are large-scale quenching tests (150 kg of reactor melts at 3000 K) and KROTOS are small-scale steam explosion tests (5 kg of melt).

The main objective of the KROTOS tests was to investigate if a strong trigger would yield a more energetic steam explosion than observed in the past. Outcomes of these tests contribute to establishing an envelope of conditions which promotes a steam explosion to occur in corium melt-water mixture. Another objective was to visualise the melt entry and mixing conditions to confirm that conditions observed in past tests were repeatable and thus representative of corium pours in the KROTOS geometry.

Visual observations confirmed that melt injection process was consistent. In a test performed with 3.6 kg of corium melt at 3100 K, initial test pressure 0.37 MPa and water subcooling 125 °C, a mild steam explosion with an estimated energy conversion efficiency of 0.15% took place (dynamic pressures shown in Figure 7.1). The measured peak pressure was 25.8 MPa. The mass mean size of the debris (0.177 mm) was as small as in the past alumina tests in which very energetic steam explosions were observed. The test outcome demonstrated that the test conditions were within the envelope for triggered explosion to take place with reactor-type melts. However, the future tests must determine reason(s) for the relatively low yield of the explosion.

FARO tests were performed in saturated water (in-vessel scenario) and subcooled water (ex-vessel scenario). In saturated water, the main objective was to study the melt quenching behaviour during a longer pour than in previous FARO tests. The longer pour was obtained by decreasing the release diameter from 100 mm to 50 mm. In a typical test, 175 kg

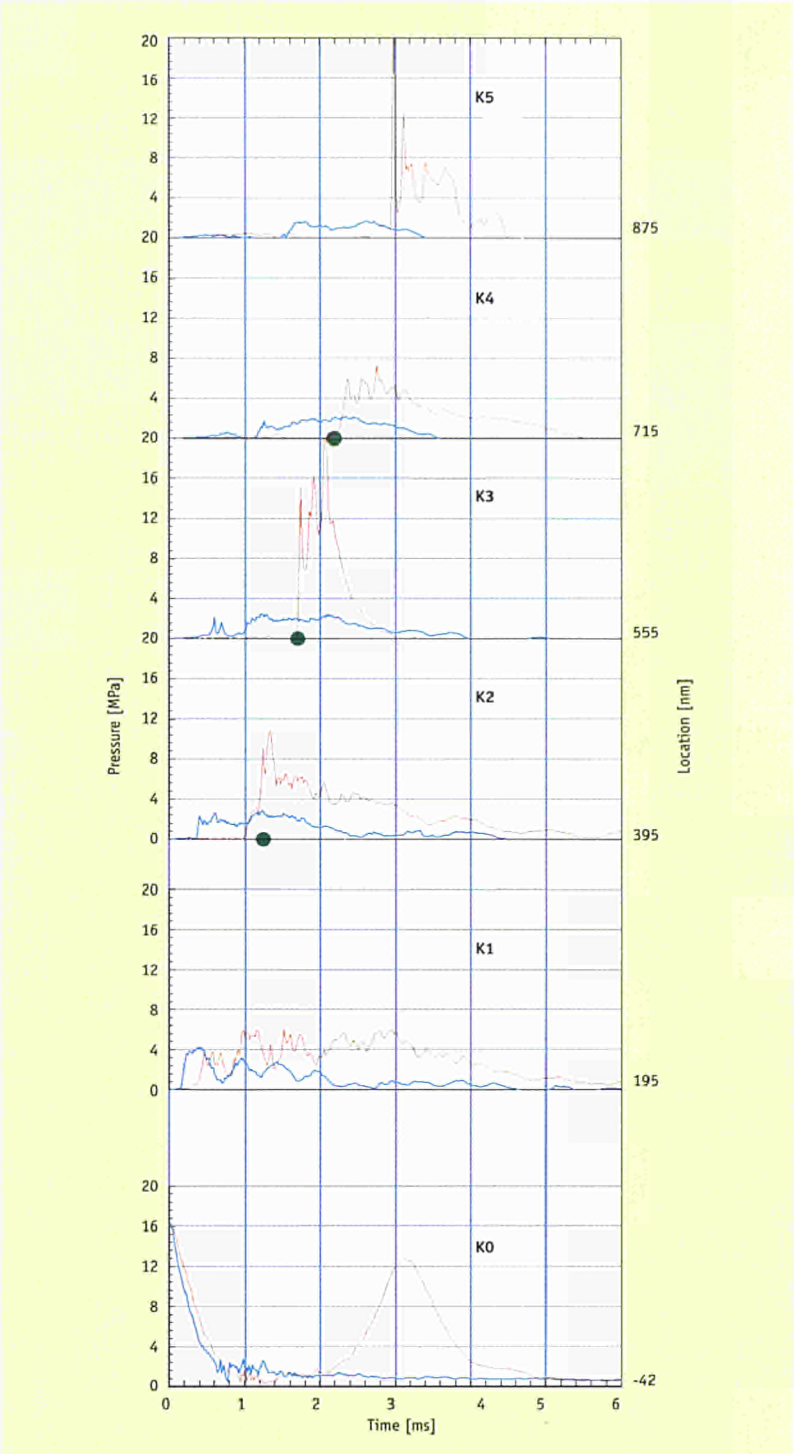


Figure 7.1: Triggering and propagation of pressure waves in the KROTOS test section (0.2 m in diameter, 1 m in height; blue lines indicate the pressure wave propagation without the melt).

[7.5] Magallon D., Huhtiniemi I., Annunziato A. Progress of the FARO/KROTOS Programme and Future Plans, *Summary of Presentation at the CSARP Meeting* Organised by US-NRC , Maryland, 4-7 May 1998.

[7.6] Huhtiniemi I., Magallon D., Field M., Gambaretti G., Klein K. KROTOS Tests KT-1 and KT-2 Data Reports, *Technical Notes N.I.98.97* and *N.I.98.186*, 1998.

[7.7] Magallon D., Huhtiniemi I., Annunziato A., Yerkess A., Addabbo C. FARO in the Fifth Framework Programme of the European Commission, *SARJ-98*, Tokyo, Japan, 4-6 November 1998.

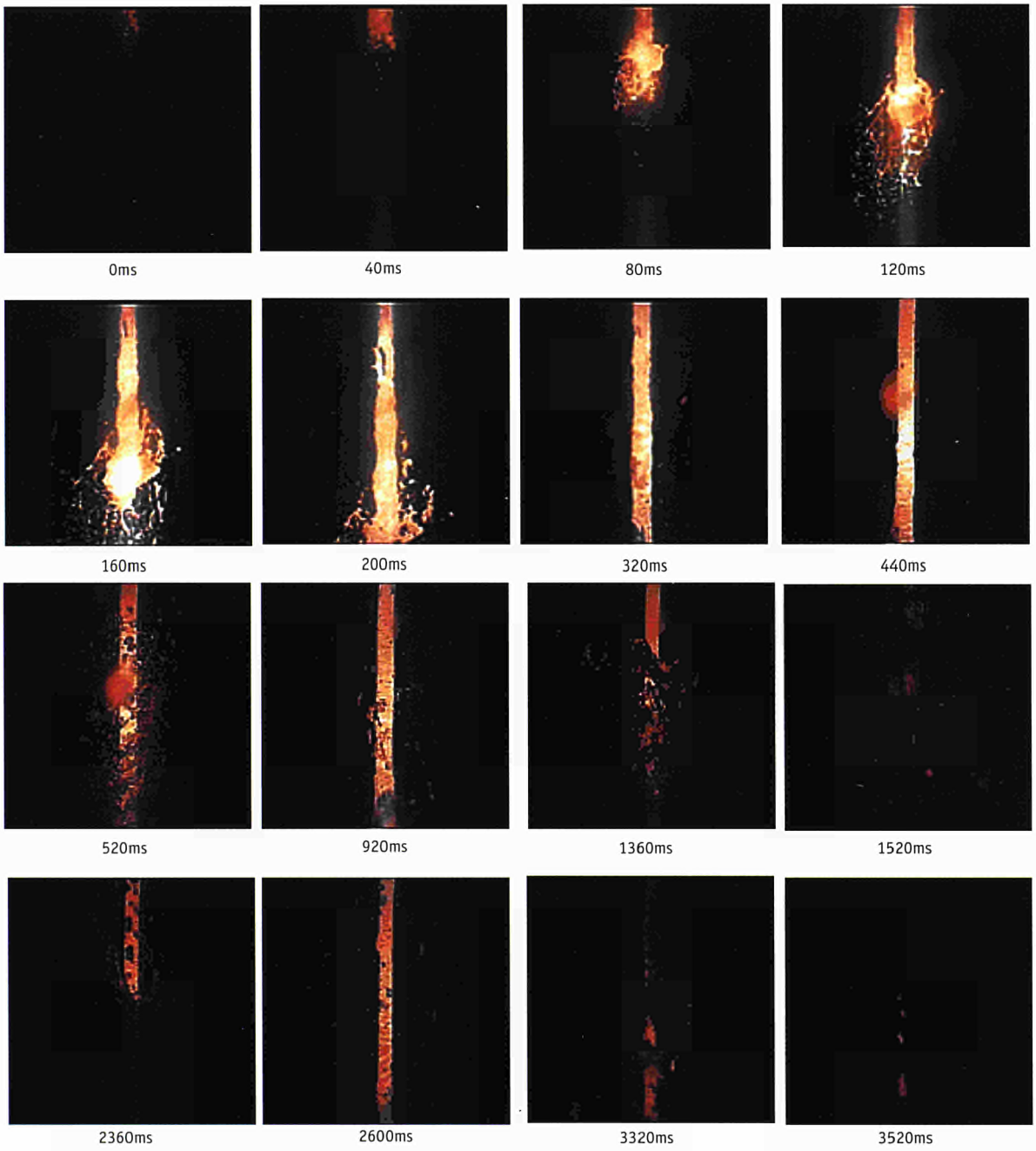


Figure 7.2: Visualisation of melt injection in a FARO test (92 kg of melt - Time 0: melt release starts: Time 320: melt contacts water, then visualisation disturbed by generated steam: Time 3520: melt release ends).

of corium melt at 3050 K were poured by gravity into 1.5-m-depth saturated water at 0.5 MPa.

The longer pour allowed for the first time to reach the phase where the erosion of the jet column was the only break-up mechanism. The vessel pressure increased quasi linearly during this phase, indicating that the quenching rate rapidly stabilised to a constant value (calculated to be about 30 MW), which did not further depend on the melt mass penetrating the water. This should allow a significant step forward in understanding the quenching process in the reactor case.

In subcooled water, tests involved up to 92 kg of corium melt poured by gravity in 1.5-m-depth subcooled water at 0.22 MPa (simulation of ex-vessel conditions). The melt quantity was intentionally reduced due to the higher risk for steam explosion than with saturated water. However, no steam explosion occurred in the tests. Very good visualisation if the jet entry conditions was obtained (Figure 7.2).

60 Characterisation of processes that govern quenching of molten Corium in water, including steam explosion (MFCI)

ISIS contact: D. Magallon

The objective of the project, co-ordinated by ISIS, is to understand the processes which govern molten corium quenching and early cooling in water, including steam explosion, and to validate the corresponding models to be applied to reactor situations. Appropriate measures can then be designed in order to favor quenching and reduce the consequences of such events. The focus is on melt steam fragmentation and mixing in water and on the role of melt physical properties in the quenching process, especially with respect to the potential for steam explosion to trigger, in both in- and ex-vessel severe accident situations.
Testing indicates that oxidic corium melt does not exhibit strong potential to induce spontaneous explosions; melt fragmentation - and thus quenching by water - is efficient while the melt is poured in the water, even for large pours; and an oxidic debris bed does not induce a large, initial, thermal load on the lower head of a reactor pressure vessel. The results allowed significant progress in modelling.

61 Corium Spreading and Coolability (CSC)

ISIS contact: D. Magallon

The objectives of the project are focused on the spreading and coolability of molten corium under various initial and boundary conditions (dry and wet spreading, flooding from the top or from the bottom of the corium) in order to provide a large experimental data base and to qualify related codes. The study of those phenomena will serve to assess efficiency, reliability and safety aspects of different designs of external core-catchers.
Great experimental effort has been carried out on the understanding of phenomena that govern melt progression and stopping. Several regimes of melt spreading have been observed, depending on the type of melts, release conditions, spreading surface, presence of water. An identification and classification of the various spreading phenomena is underway. Important experimental results are available, which allows significant progress in modelling.

COMETA code development and application

authors: A. Annunziato, C. Addabbo

The progression of severe accidents in water-cooled reactors is characterised by complex multi-phase, multi-component processes that may include the interaction of a variety of reactor materials under a wide range of parametric conditions. Areas of special importance for reactor safety evaluation and regulation include the potential for melt coolant interaction and quenching, degrees of pre-mixing and energetic escalation, debris coolability as well as thermal and mechanical response of structural components. Within the overall context of melt coolant interaction studies, the FARO experimental program is complemented by an analytical program based on the development and application of the COMETA code.

The COMETA (Core Melt Thermalhydraulic Analysis) code is an integral system code coupling thermal-hydraulic and melt fragmentation modules for the simulation of melt coolant interaction and quenching. COMETA is composed of an Eulerian two-phase flow field with non-condensables and a Lagrangian melt field representing the jet, the droplets and the debris components. Melt coolant interaction and fragmentation is described by an original model which provides the local erosion rate on the basis of an interpolated Jet Breakup Length $(L/D_j = f(We,Fr,\ldots)$ correlation with melt drops diameter calculated on the basis of the Weber number criterion. The eventual unfragmented melt relocates on the vessel bottom plate forming a fused debris bed agglomerate.

The code include a model for hydrogen generation from metallic components based on validated correlations and also an empirical model for hydrogen generation from oxidic components based on the experimental evidence acquired in the FARO experiments. Heat transfer from the fused debris-bed to the coolant is accounted for by the energy conservation equation; notionally, the porous heat transfer surface area of the fused debris is assumed equal to be the equivalent hemisphere surface area multiplied by a factor of 2.5.

COMETA has been consistently applied for FARO test design calculation and pre- and post-test analysis of the test results as well as for sensitivity calculations (Figure 7.3) to bind the influence of major parameters (e.g.; system pressure/subcooling and jet discharge characteristics) on the potential for energetic escalation [7.8]. Related activities have included

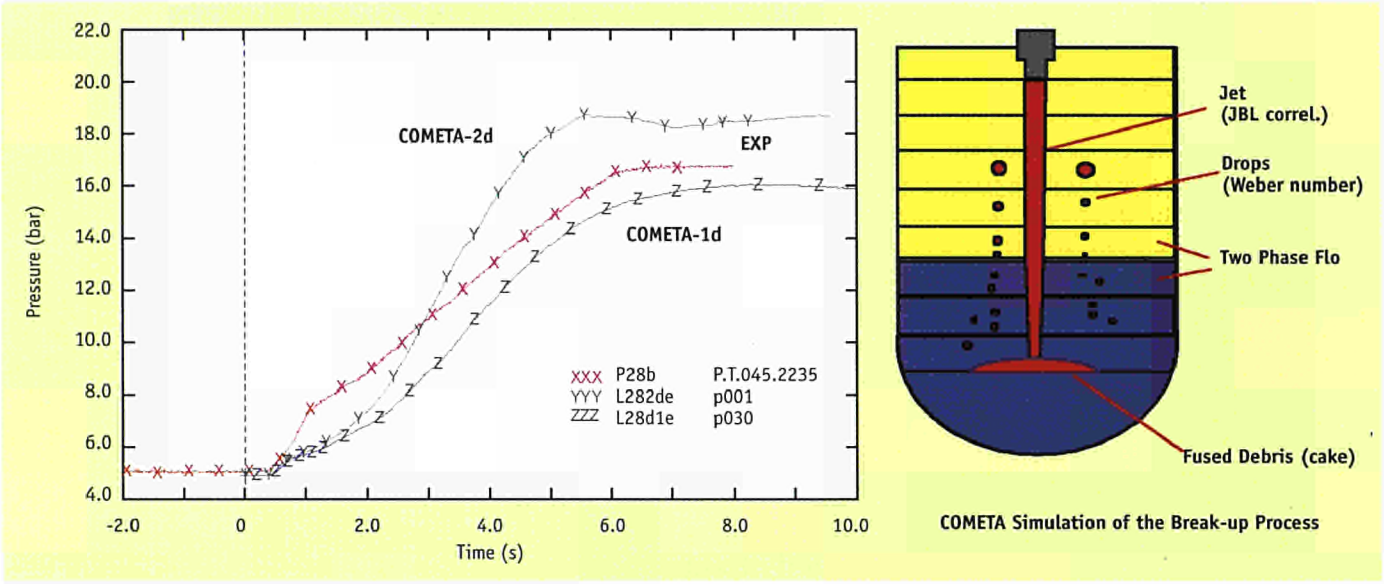


Figure 7.3: COMETA calculation of FARO-FAT Test L-28: pre-test predictions.

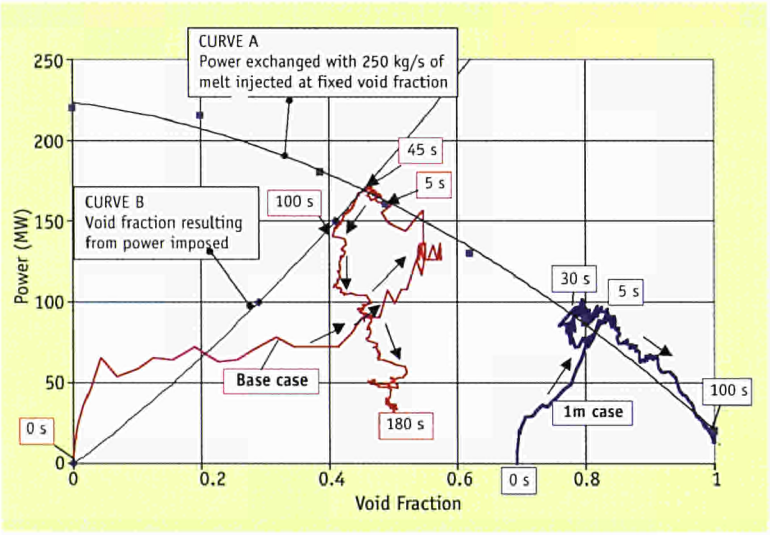


Figure 7.4: COMETA calculation of ASCO NPP: Power vs void fraction chart.

code model improvement, refinement of the numerical schemes and design of a code pre-processor package. The application and verification of the code predictive capabilities have been diversified and benchmarked against the results of similar installations such as KROTOS and PREMIX and full-scale reactor configuration (Figure 7.4) such as the ASCO-1, 3-loops 966 MWe PWR [7.9]. Requirements for coupling COMETA with the IKE-IDEMO steam explosion model and with the in-house SEURBNUK/EURDYN structural model have been assessed. The COMETA code user's manual has been compiled [7.10] and the code distributed to interested EC institutional and industrial research organisations.

In the evaluation of reactor safety margins, there is an emerging need to quantify, insofar possible or practical, the uncertainties associated with the code predicted results in order to provide the basis for the adoption of 'best-estimated' rather than of restrictive 'conservative' assumptions. Uncertainties may result from modelling and numerical deficiencies as well as from the selection of code option input parameters or even from user and computer effect. Taking this into account, the uncertainty associated with the predicted results provided by pre-mixing codes in the frame of the OECD-CSNI International Standard Problem 39 (ISP-39) on FARO Test L-14, have been benchmarked through a Fast Fourier Transform (FFT) methodology [7.11].

[7.8] Annunziato A., Pla P., Addabbo C. Analysis of Test Options for FARO Test L-29 by COMETA Code *EC/SCA MFCI Meeting*, Stockholm (Sweden), June 25, 1998.

[7.9] Pla P., Annunziato A. Analisis de la Fenomenologia de Interaccion Combustibile Fundido Refrigerante mediante Codigo COMETA *24 Reunion Anual de la Sociedad Nuclear Espanola*, Valladolid (Spain), October 14-16, 1998.

[7.10] Annunziato A., Addabbo C. COMETA User's Manual *S.P.I. 98.130*, 1998.

[7.11] D'Auria F., Galassi G.M., Addabbo C., Annunziato A. Application of the FFT Uncertainty Quantification Methodology to the FARO OECD-CSNI ISP-39 *SAMO '98*, Venice (Italy), April 19-22, 1998.

STORM aerosol experiments

author: R. Hummel

The (Simplified Tests On Resuspension Mechanism) STORM project, which was started back in 1991, has been completed and all remaining objectives have been fulfilled during 1998. The last tests on aerosol deposition and resuspension using mixtures of soluble (CsOH) and insoluble (SnO_2) aerosols were successfully performed. A broad reliable database is now available for future research.

During the STORM project a number of advanced measurement techniques were developed and optimised. (Among them two different on-line laser techniques, a non-intrusive deposit thickness measurement with micron resolution, and two sampling stations). The instruments proved again very reliable during 1998 and they offer a large potential for future applications.

The STORM project improved the understanding of the physics of deposition and resuspension phenomena. On behalf of the deposition, different deposition mechanisms were studied. Thermophoretic deposition proved to be a major mechanism for aerosol retention. Resuspension consists of the two phenomena denudation and erosion. Denudation appears as quick process with high mass contribution in short time. Erosion is a continuous process with a low mass contribution per unit time but a significant contribution (~ 50%) to the total resuspended mass after a long resuspension phase.

Important improvements were made on behalf of the CAESAR resuspension code. Its adhesion model was improved taking also the wall roughness into account. Based on CÆSAR, a simplified resuspension model was developed to be included in commercial codes. This model was validated against more than 60 series of experimental data, including several STORM tests. Another important activity was the organisation, coordination of and participation to the International Standard Problem ISP-40. It was endorsed by the OECD and based on the STORM test SR11. More than 50 submissions on both parts of the exercise (deposition and resuspension) were analysed. OECD and the more than 25 participating international organisations acknowledged the outstanding quality of the exercise.

In the second half of 1998 the CONGA experiments on the effect of aerosol deposition on the condensation heat transfer capability of a PWR heat exchanger were performed. Nearly no deposit was formed under normal carrier gas flow conditions (i.e. natural convection), thus no changes in heat transfer were observed. The presence of soluble material (CsOH by 20% wt.) in the gas led to a further reduction of deposited material due to the wash-off effect.

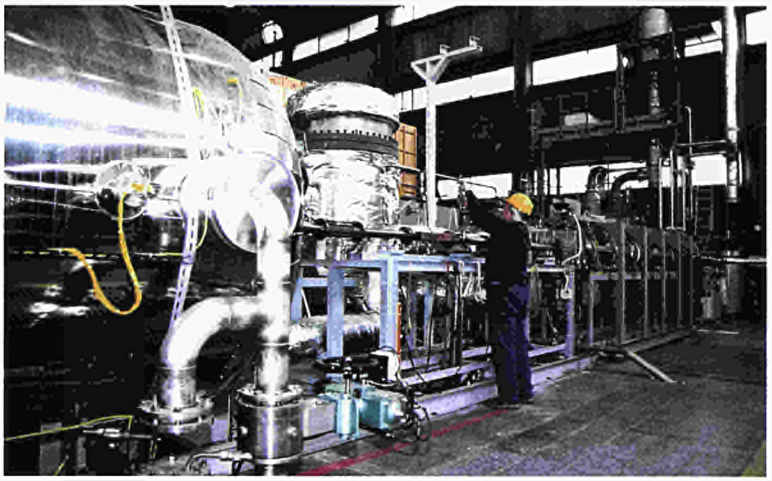


Figure 7.5: STORM (Simplified Tests On Resuspension Mechanism) experimental facility. The foreground shows the mixing vessel (ageing of aerosol) followed by the test pipe with different instruments attached.

The overall goal of the STORM project to supply a broad and reliable database and to develop a successful and recognised resuspension code has been completed in 1998.

62 Containment behaviour in the event of core melt with large gases and aerosol releases (CONGA)

ISIS contact: R. Hummel

The objective of the CONGA experimental program carried out at JRC Ispra in 1998 was the determination of (possible) degradation of heat performance under severe accident conditions in the presence of aerosol. For this study a PWR heat exchanger (HX) mock-up was installed in the STORM facility. The HX consisted of 24 tubes arranged in 4 rows, each tube with nozzles inside to allow a good mixing and equal and constant cooling water flow in the tubes. The cooling water temperature was measured with two thermocouples in the lower (inlet) header of the HX mock-up and at the exit of every second tube in the upper (outlet) header. This way it was possible to quantify the effect of aerosol deposition on different rows.
After assembling the facility, the four aerosol tests were successfully performed in the second half of

1998. In all cases the desired boundary conditions were reached as foreseen in the test matrix. After 2-3 hours of aerosol injection, with pure solid SnO2 particles or with SnO_2/CsOH mixtures, only a very thin deposit was observed on the HX finned tubes. The main outcome of the CONGA experiments was that the HX performance does not significantly degrade in the presence of aerosol.

PHEBUS FP (Fission Product) experimental programme

author : R. Zeyen

Good progress has been made in the preparation of the upcoming debris bed experiment FPT4 (Fission Product Test). The test date has not shifted significantly and is still scheduled for June 1999. This test required quite novel techniques mainly in the preparation of the 6 kg of irradiated fuel debris and its assembly into its sophisticated test section. It will be followed 8 months later by the bundle test FPT2 in partially hydrogen-rich conditions.

A strong Swiss in-kind participation to the programme has begun and has given first results on FPT4 filter loading capabilities. More work is foreseen in the areas of post-irradiation fuel analysis and experimental iodine chemistry studies. ISIS is active in helping to direct this work to technical and analytical objectives.

Consolidated results from FPT0 and 1 became available this year, (final reports from FPT0 are due for early 1999), a fact reflected in a number of publications, giving first ideas on the new findings coming out of Phebus. ISIS has made a thorough review of the draft experimental reports, on the basis of its analytical and technical experience, and its comments are being factored into the final versions. A considerable amount of SCA work is also ongoing with the effort of maximising the scientific outcome from Phebus and its integration into EC safety research.

Under ISIS coordination, the FPT3 test objectives have been agreed upon between all partners, both from the PWR and BWR communities, as a test involving interaction between irradiated fuel rods and boron carbide control material instead of a mixture of silver, indium and cadmium.

Working groups and the Steering Committee have each met twice this year (in Spring at Ispra, Italy and in Autumn at Cadarache, France) for regular technical and decision-making sessions. The Phebus programme is now well prepared for the decisive test year 1999, and ISIS is playing an important role in keeping this unique project on track.

PHEBUS FP (Fission Product) analytical programme

author: A.V. Jones

ISIS analytical activities for Phebus have three objectives: to define the objectives of each test, to interpret the results, and to validate and if necessary improve the computer models available for the simulation of the major severe accident phenomena investigated in Phebus. The work is done in collaboration with the Project team and with analysts from most of the EU member states as well as the other Phebus partner countries including the US, Canada, Japan, Korea and Switzerland. The biannual progress meetings attract large numbers of participants from dozens of organisations, and have become major events in severe accident research. A further theme of growing importance in the analytical work is the encouragement and facilitation of the transfer of information coming from Phebus to the day-to-day problems of regulators, designers and operators in the member countries.

In 1998 good progress was made with the interpretation and analysis of the results from the first test, FPT0, and interim interpretation reports have been produced concerning bundle degradation and fission product release, and, in draft form, concerning chemical phenomena in the model containment vessel. FPT0 work is now concentrating on the release, transport and deposition of fission product vapours and aerosols in the circuit and containment, where numerous calculations have been made, but the vital experimental data for comparison are only now being released.

Data from test FPT1, similar to FPT0 but with irradiated fuel, appear to confirm the lessons from FPT0. There is considerable safety-driven analytical interest in the transport of caesium seen after shutdown in this test, and in the reasons for the apparent decrease in the fraction of volatile iodine observed at the inlet to the containment vessel, as compared with FPT0. More detail on the analysis of test results is to be found in the following sections. Test FPT4S, a quite different type of experiment in the Phebus reactor, focused on the late stages of degradation and the release of low-volatile fission products and transuranium elements, has now been fully defined, and the experimental preparations are in progress. The same is true for FPT2 (similar to FPT1 but with low steam flow).

The initially rather slow output of data and interpretation information from Phebus, only to be

expected in experiments of such complexity, perhaps led to the impact of Phebus on safety thinking being undervalued. Together with IPSN, ISIS organised a seminar in January at Cadarache, attended by about 200 people, to publicise Phebus in the technical community. The two organisations also set up a one-year task force, the Ad Hoc Group, to consider the potential impact on safety thinking of Phebus, and to provide guidance on future tests in the facility. The Group's members, all drawn from European regulatory organisations, utilities and constructors, recognised that the impact of Phebus was potentially great, but warned against jumping to conclusions based on preliminary results from the first tests of the series. They confirmed the choice of tests and their conditions, as documented in the Test Matrix, and recommended further tests, focused on degradation behaviour and the source term from cores including MOX and/or high burnup fuel. The final report of the Ad Hoc Group will appear shortly.

Bundle Degradation and Fission Product Release

ISIS co-ordinates benchmarking exercises and technical discussion on the behaviour inside the Phebus bundle. The analysis of the first two Phebus experiments has led to insights that are feeding back into calculational tools for reactor analysis. In particular more attention is being paid to processes governing the production of hydrogen – the oxidation of molten or dissolved Zircaloy is now taken into account in most codes. Other findings are less well understood. It is not known why the temperature at which the Zircaloy cladding starts to relocate downwards was higher in the two Phebus experiments than in tests conducted elsewhere.

At JRC some progress was made in understanding the swelling of irradiated fuel rods during severe accidents – in particular the influence of the heat-up rate. The FPT-1 fuel rods were modelled with three different codes. One of these, LAKU, was able to reproduce the observed increase in diameter of the Phebus FPT-1 satisfactorily.

The fission product release in Phebus surprised analysts. The release of volatiles in FPT-0 was higher than expected for non-irradiated fuel and the release from the irradiated FPT-1 bundle was slightly lower. The release of semi-volatiles was very low – much lower than experience from separate effect experiments would have suggested. More detailed analysis of release models in reactor safety computer codes highlighted important differences between the code models themselves but did not explain why the experiment behaved as it did.

Circuit Transport and Deposition

ISIS' work on nuclear aerosols, both in relation to Phebus and to STORM, was highlighted at the OECD NEA Specialist Workshop on Nuclear Aerosols, held at Cologne (Germany) in June, where ISIS authors contributed several papers and contributed to the session summaries and the conclusions which are the main output to the CSNI and the nuclear safety community. The areas of safety that were identified as needing considerable research included resuspension and revaporisation of circuit deposits.

The results of analytical activities at ISIS continued to be presented at the Interpretation Circles (IC). Work related to the analysis of aerosol FPT0 and FPT1 data was presented at the Circuit and Containment Aerosol IC: a simple kinetic model for aerosol resuspension was derived, according to which negligible resuspension would have occurred in the FPT0 circuit. A numerical simulation of thermophoretic particle deposition in a turbulent boundary layer suggested that thermophoretic deposition considerably enhances turbulent deposition; and a one-dimensional formula for the revaporization rate (which gave good agreement with VTT separate-effects tests) was considered useful in understanding the observed caesium behaviour after shutdown in FPT1.

In a related development, particle deposition in laminar flow, important in the analysis of thermal gradient tubes and in the interpretation of nucleation experiments, has been analysed in terms of the heat-mass transfer analogy.

Containment Thermal-hydraulics and Aerosol Physics

The conclusion of numerous containment thermal hydraulics calculations for the FPT0 and FPT1 containment with different numerical codes showed that experimental data for temperature, pressure, and humidity are well reproduced. Analysis of aerosol behaviour in the containment, however, has proven to be a challenging task, partly due to the difficulty in predicting the main containment-wall deposition processes. ISIS has been reviewing such processes; previous conclusions that aerosol charging was not responsible for the wall deposits observed in FPT0 and FPT1 may be revised.

The analysis of the containment behaviour in Phebus test FPT-1 using Version.1.12 of the CONTAIN code, was concluded in 1998. The agreement with the time-dependent, averaged thermal hydraulics quantities such as pressure, temperature and relative humidity is rather good. It is a little surprising that it

is possible to capture the key thermal hydaulics aspects of the Phebus containment behaviour with a single compartment code. This is probably due to the fact that two-phase mixing makes the wall and gas temperatures, and thus, also the relative humidity, uniform. The aerosol injection into the containment was based on estimates since the actual data were not yet available. The calculational results regarding the build-up and settling of the aerosols gave a peak which was too early and a 40% too high. However, it was found that a weaker and later injection could approximate the aerosol results better and that this did not disturb the thermal hydraulics results. Now that the definitive experimental injection data are avail-able for FPTO, they will be compared to the adjusted injected source in the code. A complementary analysis of aerosol behaviour in the PITEAS separate-effect experiments has been made with the same code. Within experimental accuracy, the predictions for aerosol deposition are quite good. In the future, the more detailed multi-compartment code COCOSYS from GRS Cologne will be used for the Phebus containment behaviour analysis.

Fission Product Chemistry

The chemistry of the radiologically important element iodine has been poorly modelled in the past. The crucial role of silver from degrading control rods in the iodine chemistry had been underestimated. On the other hand, radiolytic generation of volatile forms of iodine, on which the models had previously concentrated, has been found to make a relatively small contribution to the total release compared with volatile iodine coming from the reactor cooling circuit or released by painted surfaces within the containment. As a contribution to the new generation of models and codes being developed in response to this insight, a "resistance-in-series" model for the reaction of iodine with silver particles in the sump under severe accident conditions was developed as part of the ISIS contribution to the Containment Chemistry IC. The model has been incorporated in the semi-empirical containment iodine chemistry code, IMPAIR3, and analyses of the FPT0 and FPT1 iodine sump behaviour are under way. The model has also been extended to study molecular iodine reactions with silver particles in the gas phase [7.12]. Sensitivity calculations showed that under FPT1 containment condition the importance of this reaction is small due to the rapid settling of aerosol particles and the small gaseous iodine concentration. The reaction may be of more importance in the circuit, where both concentrations and temperatures are higher.

63 *Iodine chemistry*

ISIS contact: Y. Drossinos

Iodine is one of the most important fission products that could be released in the event of a severe reactor accident. Experimental data from the Phebus-FP programme indicated that current iodine chemistry models do not treat correctly all iodine-related phenomena that could be important in a reactor accident. The Iodine Chemistry project concentrated on the effect of silver on iodine volatility from the sump under severe accident conditions.
The project was focused on understanding and quantifying the effects of silver on iodine behaviour, on providing new experimental data that were used to validate and improve existing models, and on stimulating code development. The programme provided extensive experimental kinetic data on the reaction of aqueous iodine with silver surfaces. Separate-effects experiments confirmed previous results that iodine volatility from irradiated iodide solutions was greatly reduced in the presence of excess silver, and models were developed to describe this effect. The models were subsequently integrated in the most commonly used containment iodine chemistry codes.

[7.12] Krausmann E., Drossinos, Y. A sensitivity analysis of the Ag-I2 reaction in the gas phase under Phebus FPT1 conditions *JRC Technical Note*, ST-PHEBEN(99)-D10, 1998.

[7.13] Von der Hardt P., Schwarz M. An International Severe Accident Research Programme: Phebus FP. International Journal of Nuclear Power, India, Vol 12, No. 3, ISSN 0971-9911, 1998.

[7.14] Areia Capitao J., Von der Hardt P., Jones A.V. The Role of the Phebus FP Experiments. Jahrestagung Kerntechnik '98, KTG, 26-28th May Munich (D), 1998,

[7.15] Clement B., Ktorza C., Jones A.V., Zeyen R. Status and Main Findings of the Phebus FP Programme. SARJ-98 - *Workshop on Severe Accident Research*, Tokyo, 4-6 November, 1998

[7.16] Drossinos Y., Jones A.V., Haste T.J., Kissane M. PHEBEN: Benchmarking Release, Circuit and Containment Codes Against Phebus FP: Intermediate Interpretation Report - Containment Chemistry. *JRC Technical Note I.98.187*, 1998.

[7.17] Ezquerra Larrode' F., Housiadas C., Drossinos Y. Supersaturation Ratio for Combined Graetz Problem. In *Proceedings of the 5th International Aerosol Conference*, Edinburgh, 12-18th September 1998; J. Aerosol Sci. V.29, Suppl.1, 1998.

64 Joint Safety Research Index (JSRI)

ISIS contact: A.V. Jones

The objective of the project is to produce a computer-based catalogue of light water reactor safety research being performed in Europe, with emphasis on severe accident aspects. The 13 partners cover all the EU countries with nuclear programmes, and certain completeness has been achieved. The completed Index, in the shape of a computer programme with search facilities, will be made generally available, and is intended for managers of research programmes looking for an overview of current research activities, and for leaders of research teams who require contact points for the efficient exchange of information. JRC has contributed project files its the major experimental programmes (FARO, KROTOS, STORM,...) as well as on its code development and validation activities and other relevant work such as in PSA.

65 Fission product release and speciation

ISIS contact: I. Shepherd

ISIS has completed work on its main task in the FPREL project. The work involved comparing mechanistic fission product release models with more empirical ones. It was found that fundamental differences in the way that intergranular diffusion was handled accounted for choices in the integration scheme used and hence in the results obtained. An error was found in the USNRC code VICTORIA. When this was corrected it produced results comparable to the IPSN code ELSA. The project as a whole was delayed because of instrumentation problems on the OSPREY test facility at Winfrith. When these tests are completed ISIS will analyse the results using lessons learnt in the first phase of the project.

66 Validation of severe accident code models for fission product release, transport, deposition and chemistry against Phebus FP (PHEBEN)

ISIS contact: A.V. Jones

To ensure that the jigsaw of interacting phenomena revealed by separate-effect tests is pieced together to give an accurate picture of the behaviour of a nuclear reactor under severe accident conditions it is essential to perform integral tests such as those of the Phebus FP series. The role of ISIS is to involve the European partners as thoroughly as possible in the planning of the Phebus tests and in understanding their results, so as to learn as much as possible in support of accident mitigation measures and accident management strategies. PHEBEN encourages the desired involvement through the benchmarking of codes (both best-estimate models and safety assessment tools) against Phebus results.

Good progress has been made in 1998, with detailed investigation of the phenomena in the Phebus circuit and containment, Phebus-inspired model development and model validation against data from Phebus and elsewhere. Release models do not adequately consider the bundle state, but model development elsewhere may address this deficiency. Circuit deposition is less concentrated in the steam generator than expected, and the small but significant fraction of iodine leaving the circuit in gaseous form is not predicted; these observations have stimulated model development. Containment thermal hydraulics are well predicted; aerosol deposition rates and spatial distribution are less well treated. Recognition that silver from control rods influences iodine behaviour has resulted in Ag/I models being introduced into major iodine chemistry codes in Europe; attention is now turning to organic iodine in the containment which may pose a greater challenge to removal measures.

[7.18] Haste T.J., Reeks M., Jones A.V., Shepherd I., Kissane M. PHEBEN: Benchmarking Release, Circuit and Containment Codes Against Phebus FP: Intermediate Interpretation Report - Fission Product Release and Transport in the Circuit. *JRC Technical Note* I.98.188, 1998.

[7.19] Housiadas C., Schrader K-H, Drossinos Y. Dehumidification of Air Flow Through Cooling at Sub-Freezing Temperatures. *International Journal on Heat and Mass Transfer*, Vol. 210, 1821-1831, 1998.

[7.20] Jones A.V., Haste T.J. PHEBEN: Benchmarking Release, Circuit and Containment Codes Against Phebus FP: Second Six-Monthly Progress Report. *JRC Technical Note* I.98.153, 1998.

[7.21] Jones A.V., Haste T.J., Kissane M. PHEBEN: Benchmarking Release, Circuit and Containment Codes Against Phebus FP: Intermediate Summary Report. *JRC Technical Note* I.98.201, 1998.

67 Assessment of models for fission product revaporization (REVAP-ASSESS)

ISIS contact: I. Drossinos

The objective of REVAP-ASSESS was to determine the adequacy of current state-of-the art fission product models when applied to situations during a postulated severe accident in a nuclear power plant in which revaporization takes place. The ISIS contribution was the development of a one-dimensional, analytical expression for the revaporization rate as a function of time based on the heat-mass transfer analysis (Graetz-Nusselt problem). Analytical results compared favourably with separate-effects experiments of caesium hydroxide revaporization in steam.
The aims of the project are relevant to current ISIS activities in nuclear fission safety, aerosol physics, and fluid dynamics.

68 Archive for Source Term Information and System Models (ASTERISM)

ISIS contact: A.V. Jones

The objectives of the project, which seeks to apply ISIS expertise in nuclear safety and information technology to help capture and preserve the outcomes of EC-funded research, are:

- *to compile a catalogue of the information (data as well as models) resulting from the Source Term projects funded under the EC's Fourth Framework Programme: Nuclear Fission Safety programme.*
- *to design an appropriate archiving system for this information*
- *to set up a pilot archive using a subset of data available at the time of its creation and gather user feedback on its performance. It is intended that the pilot archive should be highly flexible so that it could be extended to encompass other nuclear fission safety projects.*

A draft catalogue of the results of the projects has been set up, and design of the database is in progress. It has the unusual feature of incorporating tables, formulae, text, and blocks of computer code, and focuses on making the results available for easy re-use.

69 Validation strategies for severe accident codes (VASA)

ISIS contact: A.V. Jones

The objectives of this project (co-ordinated by GRS, Cologne, Germany) are to bring together current approaches and requirements for validation strategies for severe accident codes in the various European countries, to identify strengths and weaknesses in our understanding, and to attempt to reach a consensus on the further steps needed for the development of a common European validation strategy for such codes. The output should be a firmer basis for the development and practical implementation of engineered safety features and accident management measures. ISIS is involved both as a model developer and as a code validator, and because of the opportunity the project offers for dialogue with the user community (designers, utilities and safety authorities). The first step, establishing and comparing the approaches in the various organisations and countries is underway.

70 Investigation of core behaviour (COBE)

ISIS contact: I. Shepherd

The COBE shared-cost action project co-ordinated by JRC aims to advance the capability of calculating behaviour in a reactor vessel up to vessel melt-through,

[7.22] Jones A.V. JRC Comments on Project Proposals to Simplify the Instrumentation of Phebus Test FPT2. *JRC Technical Note* I.98.80, 1998.
[7.23] Keinhorst G., Von der Hardt P., Jones A.V. The Phebus FP Experiments and Related EU-sponsored Research Activities on Severe Accidents. *Jahrestagung Kerntechnik*, Munich May 26-28, 1998
[7.24] Kourti N. Modelling Fuel Swelling in Severe Accidents *JRC Technical Note* I.98.117, 1998.
[7.25] Kourti N. Comparison of Bundle Degradation in Phebus FPT0 and FPT1. *JRC Technical Note* I.99.06, 1999.
[7.26] Kroeger C., Drossinos Y. A Numerical Simulation of Particle Deposition in the Diffusion-Impaction Regime in the Presence of a Temperature Gradient. *3rd International Conference on Multiphase Flow* (ICMF), Lyon (F), 8-12th June 1998.
[7.27] Lewi J., Schwarz M., Von der Hardt P. Phebus FP: Fission Product Behaviour. *21st GRS-Fachgespraech*, 3-4th November 1997, Garching (D), ATW, Vo.43, 92-96, 1998.

so that the efficacy of accident management strategies can be assessed. Eleven organisations are involved, from France, Germany, Italy, Spain and the UK. This three-year project concludes at the end of January 1999, and the main objectives have been achieved. A key item is the successful performance of a series of experiments at Forschungszentrum Karlsruhe in which nuclear fuel rod simulators were quenched with water from temperatures up to 2000°C in both single rod and bundle configurations, under conditions typical of those found in the management of a severe accident in a pressurised water reactor. The results have been used to develop and test advanced models of fuel rod behaviour in quench situations. Models have also been developed for melt and relocation of core materials to the lower head, with code validation against data from the Phebus FP programme, the TMI-2 accident, and other relevant sources. JRC has contributed by assessing degradation of irradiated fuel at high temperatures (>2000°C), in particular developing a new model of fuel swelling which compares favourably with existing data.

71 Oxidation Phenomena in Severe Accidents (OPSA)

ISIS contact: I. Shepherd

The companion OPSA project, also co-ordinated by JRC, investigates oxidation reactions that may play an important role in the late phase of water reactor severe accidents. A particular concern is air ingress into the core, which may lead to increased release of fission products such as the highly toxic ruthenium into the environment. The project has five partners, from France, Italy and Germany, and reaches the end of its $2^1/_2$-year term in June 1999. Good progress has been made in both the experimental and theoretical areas, with assessment of the conditions which may lead to air ingress in-reactor and the performance of ex-reactor oxidation experiments in steam and air up to melting of the Zircaloy cladding (~2000°C). The CODEX-AIT1 experiment at AEKI, Budapest demonstrated for the first time that air ingress could lead to an uncontrolled temperature excursion from as low as 900°C, as against ~1500°C in the steam environment which is found before air ingress. JRC has played a leading role in the accompanying theoretical work, modifying the French ICARE2 code for air ingress and successfully applying it to understand the thermal behaviour of the facility, help define the test conditions and calculate successfully the results obtained. JRC has also advised on aerosol behaviour, applying knowledge gained in the STORM programme to improve instrumentation in the CODEX facility and interpret the test results.

72 Multidimensional simulation of hydrogen distribution and turbulent combustion in severe accidents (Hydrogen Risk)

ISIS contact: H. Städtke

During severe accidents with core melt in Light Water Reactors, large quantities of hydrogen may be generated and released to the reactor containment. Possible ignition of the resulting hydrogen-air-steam mixture and subsequent deflagration, flame acceleration or even transition to detonation could threaten the containment integrity with the consequence of radioactive releases. For this reason a strong need exists for a reliable simulation of the major processes involved like hydrogen distribution in the containment and various modes of combustion including the possibility of deflagration-to-detonation transition.
The present project deals with the development and verification of physical models and related numerical solution strategies for hydrogen distribution, turbulent combustion and mitigation methods, suited for the application in multi-dimensional CFD codes currently under development in different partners' institutions. High spatial resolution of governing processes provided by CFD codes is essential for a realistic

[7.28] Schwarz M., Clement B., Ktorza C., Jones A.V., Zeyen R. The International Research Program on Severe Accidents Phebus FP: Status and Main Findings. *26th Water Reactor Safety Meeting*, Bethesda (USA), 26-28th October, 1998.

[7.29] Shepherd I. et al. Intermediate Analysis Report of Phebus FP Test FPT-0: Bundle Degradation and Release (The Ability of Codes to Reproduce Core Behaviour in FPT-0. *JRC Technical Note* I.98.206, 1998.

[7.30] Van Wijk L.G.A. Post-test Analysis for the Two PITEAS Diffusiophoresis Tests using the CONTAIN Code (Ver.1.12). *JRC Technical Note* I.98.190, 1998

[7.31] Von der Hardt P., Schwarz M. Results of the First Phebus FP Experiments. *TOPSAFE 98*, Valencia, Spain, 15-17th May 1998

[7.32] Wider H., Jones A.V., Haste T.J., Kissane M. PHEBEN: Benchmarking Release, Circuit and Containment Codes Against Phebus FP: Intermediate Interpretation Report - Containment Thermal Hydraulics and Aerosol Physics. *JRC Technical Note* I.98.189,1998.

[7.33] Wider W. Pre-Test Calculations with the Corflow Code for the First UO2/ZrO2 Spreading Test in FARO, *JRC Technical Note* No. I.98.99, 1998.

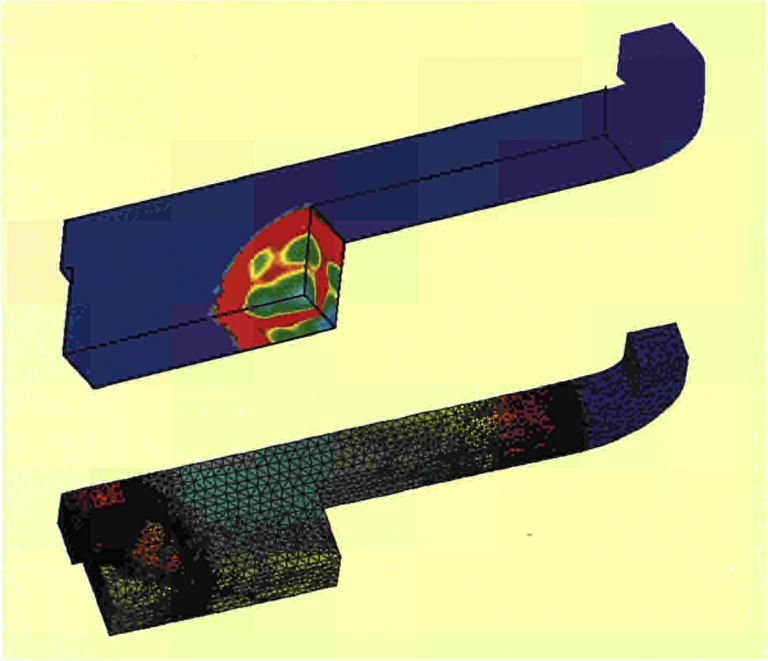


Figure 7.6: Hydrogen detonation in the RUT facility, 20% vol. concentr. of hydrogen, predicted pressure distribution at 2ms and 10ms after ignition, highest spatial resolution at detonation wave: 1.5 cm, iso-colores: 1 bar (blue) to 10 bar (red).

prediction of important local phenomena like hydrogen stratification, plume behaviour of released gases, steam condensation, flame acceleration, quenching or local detonation.
The newly developed models are verified against experimental data from differently scaled partners' test facilities:

- *laboratory-type experiments providing detailed information on turbulent H2-air flames using Laser Doppler and Laser Induced Fluorescence methods (TU Munich);*
- *intermediate scale test data on turbulent combustion (FZ Karlsruhe);*
- *large-scale data on turbulent combustion and explosion from the RUT facility (length scale 28 m) operated by the Russian Subcontractor (Kurchatov Institute).*

The specific contribution of ISIS is the development of an improved turbulent combustion model based on the eddy break-up concept. The model has been implemented into the REACFLOW code presently under development in ISIS for the numerical simulation of fast deflagration and detonation processes in gas mixtures. A specific feature of this code is an adaptive grid refinement and/or coarsening technique that allows a high spatial resolution of local steep parameter gradients like shock and detonation waves. An example of the code capability is given in Figure 7.6 showing the prediction of pressure distribution at two different time values for a detonation in the RUT facility.

Probabilistic Safety Assessment (PSA)

author: G. Cojazzi

ISIS conducted researches and networked laboratories and European Institutions on critical aspects of PSA. The main research activity performed at ISIS in the PSA domain, in the period 1995-1998, dealt with the Expert Judgement (EJ) problem. The aim is to determine how specialist assessments can be integrated in the PSA study in a formal and disciplined way to guarantee the reproducibility and accountability of their judgements and hence of the entire PSA process. This is of primary importance in Level 2 PSA, which is devoted to the quantification of severe accidents and in particular to the estimation of the frequencies of release from the containment. The research activity performed at ISIS within the expert judgement project covered two aspects:

- The development and application on study cases, relevant to severe accidents, of a new approach to expert judgement in PSA, based on knowledge engineering techniques.
- The organisation, running and documentation of a European Benchmark Exercise on expert Judgement techniques applied with reference to level 2 PSA.

In the course of 1998, the concerted action 'Benchmark Exercise on Expert Judgement techniques in PSA level 2' (BE-EJTs) has been concluded [7.34]. Phase 1 of the benchmark has been dedicated to comparison and evaluation of EJ techniques in the forecasting of the results of the ISIS FARO L-24 experiment [7.35]. Phase 2 has been carried out with reference to the assessment of the hydrogen deflagration/detonation issue in the context of a pressurized nuclear reactor of evolutionary design. The perspective of the EJ methodology KEEJAM (Knowledge Engineering Expert Judgment Acquisition and Modelling) being developed at ISIS, is that EJ is basically a knowledge problem. KEEJAM technique has been further developed and applied to both benchmark phases [7.36]. The whole activity will be fully documented and exploited in the course of 1999 and new applications will be initiated.

ISIS competence in informatics and information handling has been exploited in a project aimed at the development of a database system [7.37] for supporting level 2 PSA analysts in handling the large amount of information implied in a PSA study; a related shared cost action (PSAL2) has been worked out. Another activity carried out aimed to the further development, testing and documentation of the ASTRA code for Fault Tree analysis (see Software for the Process Industries in Chapter 4 of this Annual Report). Research on human factors has been conducted [7.38] in synergy with other researches on human factors in the area of transport safety (see ISANEW in this chapter, dedicated to the new approaches in human reliability).

73 Benchmark Exercise on Expert Judgement Techniques in PSA Level 2 (BE-EJTs)

ISIS contact: G. Cojazzi

Aim of the benchmark project is to document and compare different structured methods and techniques for handling Expert Judgement (EJ) actually adopted among a number of European Institutions. The benchmark is organised on two phases devoted respectively to the benchmarking of formal techniques for handling EJ for parameters estimates (Phase 1) and for the so called scenario development (Phase 2). A proper framework has been developed for comparing EJ methods. Five different approaches have been fully assessed and compared in phase 1 and four different approaches have been preliminary compared in phase 2.

74 A dataset for probabilistic safety analysis studies (PSAL2)

ISIS contact: G. Cojazzi, M. Delaval

The development of a Level 2 PSA study requires the collection and exploitation of a large amount of information and data. Aim of the project is to demonstrate the feasibility of establishing a dataset for supporting the PSA analysts in performing level 2 PSA studies. The information has been categorised in terms of confidentiality, reactor type, plant specific or general, physical or code output, derived from PSA studies etc. ISIS was in charge of developing the database, named VASA (Virtual Assistant for Safety Analysis) and the associated interface (see Figure 7.7 for an overview). By the end of 1998, 270 references dealing with "Hydrogen" were selected, reviewed, commented and finally entered by the project partners in the database prototype.

75 Integrated sequence analysis and new approaches to human reliability (ISANEW)

ISIS contact: P.C. Cacciabue

Primary aim of the project is to identify and review advanced existing methods dealing with dynamic reliability and human factors and to see how they can contribute to the development of an integrated sequence analysis approach. In the first year, the methods identified have been confronted with a list of requirements stemming from the needs arising from practical applications as well as from the needs of a more formal and comprehensive modelling of the human factor.

[7.34] Cojazzi G. Benchmark Exercise on Expert Judgment Techniques in PSA level 2, Minutes of the Progress Meeting, December 15-16, 1997, Ispra, European Commission, EC-JRC-ISIS, *JRC Technical Note* No. I.98.19, 1998.

[7.35] Cojazzi G., Pinola L., Pulkkinen U., The Context of the Phase I of the Benchmark Exercise on Expert Judgement Techniques in Level 2 PSA: The JRC FARO L-24 Experiment, in A.Mosleh and R.A.Bari Eds., *Proceedings of the PSAM IV International Conference on Probabilistic Safety Assessment and Management*, New York, USA., September 1998, Springer-Verlag London Limited, Londra, UK, pp. 1699-1704, 1998.

[7.36] Cojazzi G., Guida G., Pinola L., KEEJAM Expert Judgment Methodology and its Application to the Prediction of the Results of a Fuel Coolant Interaction Experiment, in A.Mosleh and R.A.Bari Eds., *Proceedings of the PSAM IV International Conference on Probabilistic Safety Assessment and Management*, New York, USA, September 1998, Springer-Verlag London Limited, Londra, UK, pp. 2119-2124, 1998.

[7.37] Realini M., Delaval M., PSA2 ASSISTANT, versione 0.4, Manuale del Programmatore, *JRC Technical Note* No. I.98.147, 1998.

[7.38] Cacciabue P.C., Hollnagel E., Human Factors Methods for Safety Assessment in Highly Automated Environments: Task Analysis, Modelling and Data, in A.Mosleh and R.A.Bari Eds., *Proceedings of the PSAM IV International Conference on Probabilistic Safety Assessment and Management*, New York, USA., September 1998, Springer-Verlag London Limited, Londra, UK, pp. 740-745, 1998.

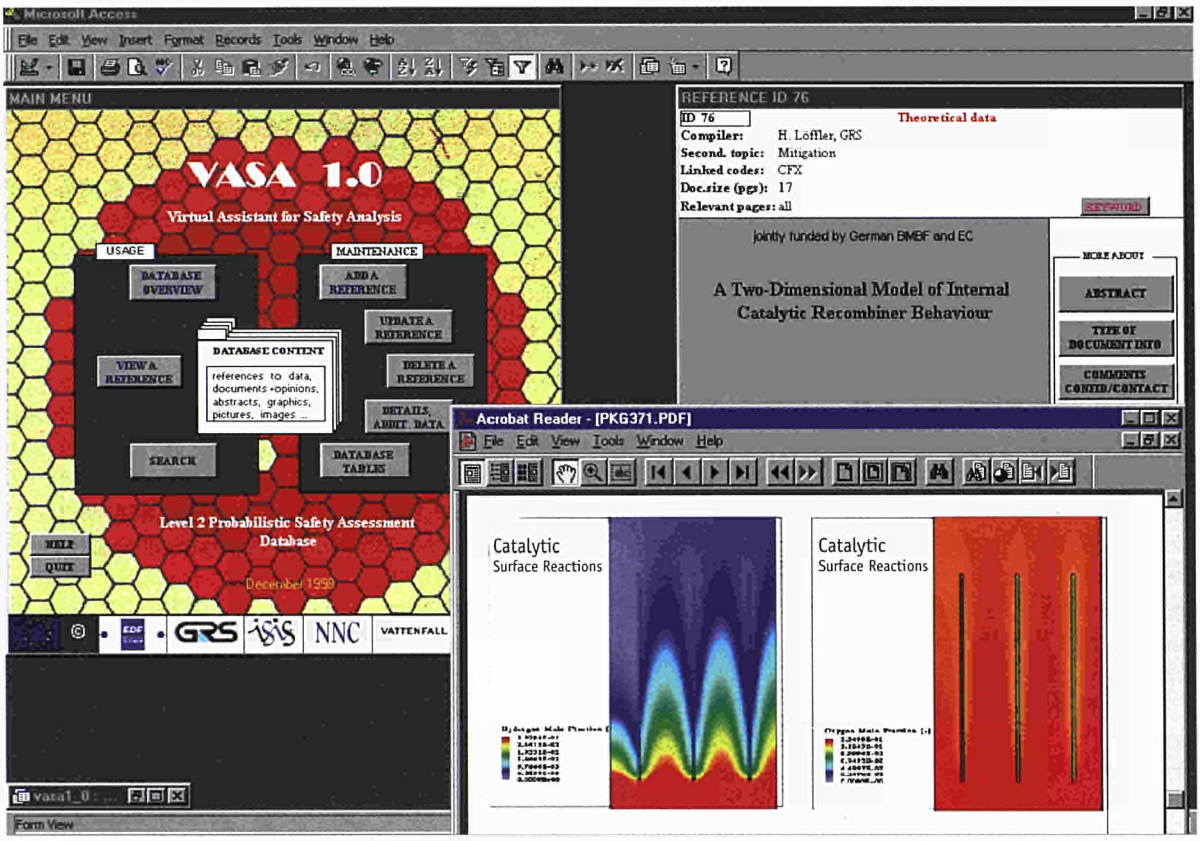


Figure 7.7: PSAL2-A dataset for Probabilistic Safety Analysis studies. VASA (Validation strategies for severe accident codes) main menu database, the simulation of cover page of a document (grey area) and a specific page of the corresponding document (coloured isographs).

76 77 Behaviour of the reactor pressure vessel under mechanical and thermal loadings caused by core melt-down and steam explosion accidents (RPVSA) and reactor vessel integrity in severe accidents (REVISA)

ISIS contact: C. Albertini

Both projects belong to the "in-vessel Core Degradation and Coolability" cluster of the Nuclear Fission Safety Programme. They are closely related and deal with vessel situations, which may be encountered in a variety of severe accident scenarios. In particular the JRC is involved in the problematics of the impact of a slug of molten corium and debris on the upper head as well as the dynamic pressure loading in the lower part of the reactor vessel due to a steam explosion. Theoretical investigations and modelling have produced strongly different and unreliable results, and therefore experiments with detailed structural mock-ups have been deemed necessary (BERDA and FLIPPER experiments of the Forschungszentrum Karlsruhe, FZK). These impact problems require a correct knowledge of the material deformation and failure processes. Accompanying investigations are thus needed to make sure that the results are transferable to the real problem and that the essential effects are adequately simulated: size effects, strain rate effects, temperature, and strain gradient effects.

The JRC has been assigned to carry out these dynamic tests for material characterisation, employing principally the Large Dynamic Test Facility (LDTF), which allows the testing of large specimens under well defined strain rates. Uniaxial (smooth and notched) and biaxial tension tests are foreseen of the materials used for the pressure vessel and its internal structures. These include: ferritic steel 20MnMoNi55 (vessel head), austenitic steel X6CrNiNb1810 (upper internal structure), ferritic steel 26NiCrMo146 (bolts), and brass (simulation of upper internals in BERDA). Specimens have been tested at room temperature and at 600° C, and at strain rates ranging from quasi-static to dynamic (200/sec) conditions. It is interesting to note that the uniaxial tensile cylindrical specimens include the following diameters: 3mm, 9mm, 30mm. The experimental results produced are utilised by the other partners in their analytical and modelling analyses.

Safety of accelerator driven systems for nuclear waste burning

author: H. Wider

Safety calculations that have been performed during the past years mostly assumed that the proton beam is not switched off when an accident occurs [7.39, 7.40]. Although it is probably easier to switch off an accelerator than to insert control rods in a critical reactor, such calculations are still relevant. With the proton beam on, the worst possible accident in a heavy metal cooled ADS appears to be a complete Loss-of-Heat Sink accident that would lead to a slow but steady heat up of the core and eventually to cladding and fuel melting. The accelerator should be switched of manually during the slow heat-up and it could also be done automatically based on high thermocouple readings. As a last resort a melt-rupture disk in the side-wall of the proton guide tube is recommended by ISIS which would fail and flood this vacuum tube with heavy liquid metal (patent [7.41]). This would block the proton beam and reduce the power to a decay heat level. This passive beam shut-off device would also be a useful back–up system for shutting down an ADS in less serious accidents such as Loss-of–Flow, beam power increase and reactivity insertion accidents.

In case that the secondary loops cannot remove heat any longer, not only the beam has to be switched off but also emergency decay heat removal is necessary. Natural circulation air cooling of the vessel outside, which has been proposed earlier by the US IFR project, is a promising approach. A Ph.D. thesis has begun on the different aspects of Reactor Vessel Air-Cooling Systems (RVACS). As a tool, the commercial UK hydrodynamics code STAR-CD is used.

Remote handling of fusion reactors

authors: F. Farfaletti-Casali, F. Andritsos, E. Ruiz

In 1998 ISIS completed its contribution to the feasibility studies related to the attachment of First Wall and Blanket modules inside the Vacuum Vessel of ITER. This was carried out in the framework of an ITER task jointly performed by a Consortium of European Fusion Association Laboratories (ISIS, Ente per le Nuove Tecnologie e l' Ambiente-ENEA, Commissariat à l' Energie Atomique-CEA, and Osterreichishe Akademie der Wissenschaften-OAW). ISIS contributed to the Control and Data acquisition systems for the Blanket test facility to be realised by ENEA. The ISIS contribution has concerned the design and technical specifications of the Control and Data acquisition system, produced on the basis of the experience acquired during the development, as a Safety critical computer system, of the control system of the heavy robotics ROBERTINO facility at ISIS. ISIS has also pursued the upgrading of the ROBERTINO facility and its Control system and has provided the procurement of additional equipment, a new robotics Calibration system, to improve the demonstration capabilities of the laboratory. The Heavy Robotics ROBERTINO facility, with the support of a CAD/CAE laboratory, where on a virtual ROBERTINO all the processes are planned, simulated and verified prior to their implementation on the real ROBERTINO, is now available for simulation and demonstration studies in the field of new technologies applications, as a spin-off of the activities carried out in the frame of the Fusion Programme. As spin-off three important competitive activities have been pursued in 1998, GENERIS, LASEROBOT and ROTIS (see Chapter 6 of this Annual Report). In addition, the thematic network ROBMAR (robotics for maritime industries) has started in November 1998; two new competitive projects PIOWC and AIPS have been proposed and approved in 1998.

[7.39] Wider H. Safety of Accelerator-driven Nuclear Waste *Burners In Proceedings of Jahrestagung Kerntechnik*, München, May, 1998.

[7.40] Maschek W., Merk B., FZK, Wider H. Some Safety Studies for Accelerator -Driven Subcritical Systems *Second International Topical Meeting on Nuclear Applications of Accelerator Technology*, AccApp'98, Gatlinburg, USA, September, 1998.

[7.41] Wider H., Schönherr H. Beam pipe with safety function for accelerator – driven nuclear systems *European patent No 9811339.7*, 1998.

Generalised software control system for industrial robots (GENERIS)

author: E. Ruiz

GENERIS is a powerful and generic software control system for robotics (Figure 7.8) has been developed in the frame of the Remote Handling activities for the Fusion Programme. As a result of the DGXIII (Telecommunications, Information Market and Exploitation of Research) Competitive Support Activities programme, this innovative software has been adapted and tested to become an industrial product for SME manufacturers of robotic systems. The software has been licensed in September 1998 to an external Italian company, named ERXA, for its commercial distribution. GENERIS has also been presented at SITEF'98 (Toulouse, France) and at BIAS'98 (International Fair for Instrumentation and Control - Milan, Italy).

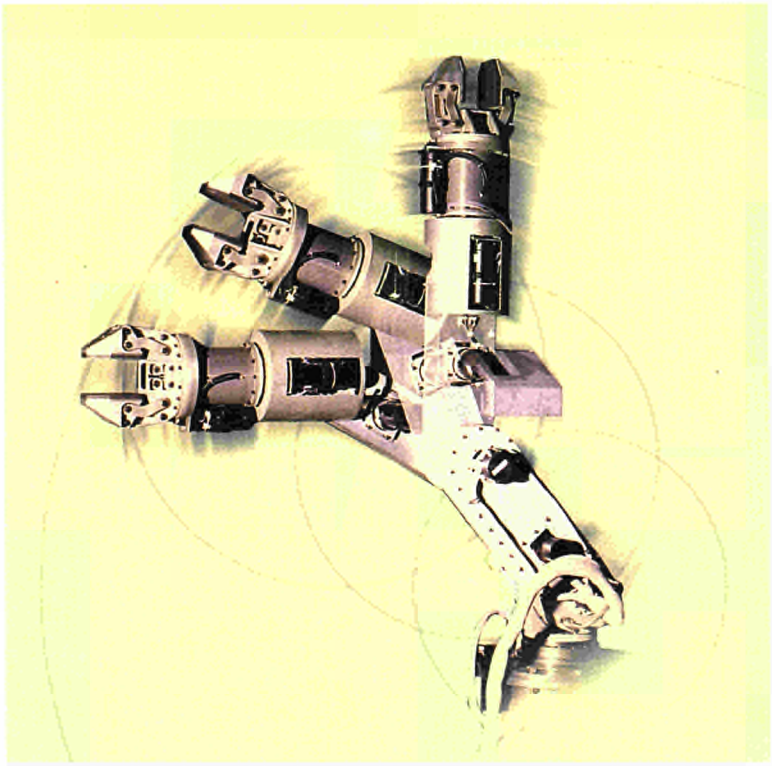


Figure 7.8: Generalised Software Control System for Industrial Robots (GENERIS): a powerful and generic software control system for robotics.

78 Validation of laser welding technology for heavy section components (LASEROBOT)

ISIS contact: E. Ruiz

The LASEROBOT project supported by the Innovation Programme, aims at validating laser-welding technology for large, heavy and thick components, by implementing a heavy robotics high power CO_2 laser welding workcell at the ROBERTINO facility (Figure 7.9). The innovative aspects of this project stands in the integration of two robotics manipulators (ROBERTINO and GAER) and various advanced tools for off-line programming, simulating, controlling, supervising and calibrating the whole system.

The year 1998 has been devoted to the design and manufacturing of the LASEROBOT components. For instance, ISIS has upgraded the ROBERTINO manipulator, designed the laser shielding equipment, interfaced the GENERIS software with the ENVISION kinematics simulator, and installed a calibration system based on the LEICA LT500 interferometer and the ROBOCAL. 1999 will be devoted to the system integration and to the experimental validation with a 20kW CO_2 laser on a mock-up prepared by FRAMATOME.

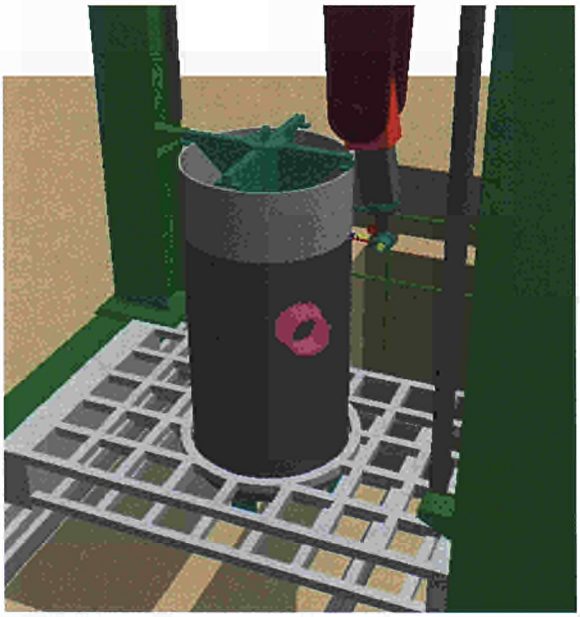


Figure 7.9: 3D simulation of laser weldings.

Nuclear safeguards

editor: A. Poucet

Safeguards control of fissile materials is performed by the Euratom Safeguards Directorate (DG XVII: Energy-ESD) and the IAEA (International Atomic Energy Agency) in the framework of the Euratom and the Non-Proliferation Treaties respectively. ISIS, as a neutral and independent organisation, gives scientific and technical support to ESD, IAEA (contributing substantially to the performance of their tasks) and support to the Russian Federation (in the framework of the TACIS programme).

To respond to new challenges in safeguards, ISIS has to carry out enabling research to develop safeguards methods and techniques. Once such methods have proven to be feasible, they may be used in direct support to Euratom and IAEA inspectorates and plant operators.

Mass/volume measurement techniques

author: B. Hunt

Safeguards activities have continued in an ever increasing manner in the field of mass/volume determinations and methodology for both accountancy and control purposes. Support activities are provided to the International Atomic Energy Agency (IAEA), Euratom Safeguards Directorate (ESD) and Technical Assistance to the Commonwealth of Independent States (TACIS).

Safeguards support activity to the IAEA has been particularly fruitful with the successful completion of a one month unattended measurement and monitoring campaign mode carried out in the TRP plant in Japan utilising equipment developed at ISIS. Equipment was left in-situ to collect data on an important process vessel requiring the inspector only to launch the program and download the data on a monthly period for analysis. A second support task proposal has been accepted by the IAEA and the Science and Technology Agency of Japan concerning an independent data collection and evaluation system. This proposal is linked to the safeguards system to be implemented in a Japanese facility where the challenge concerns the large throughput of the reprocessing facility. An exact replica of the input accountability tank has been installed in the NMCC (Nulcear Material Control Centre) premises in Tokaimura (Japan). An ISIS portable pressure measurement system will be installed and tested on this mock-up tank under the auspices of the IAEA and NMCC during the forthcoming tank calibrations in mid 1999 supplemented with studies on the parameters which may affect accuracy and reliability of verification measurements. The implementation and installation of ISIS-developed equipment for monitoring campaigns in an Indian facility has moved a step closer with the preparation of the monitoring equipment and associated 18 pressure measurement signals. A visit organised by the IAEA to the installation highlighted the need for minor improvements to the equipment to account for the working ambient conditions and layout details. Support has continued to TACIS with particular emphasis on the inauguration of the Russian Methodological Training Centre (RMTC) in Obninsk in November 1998. Part of RMTC is the Tank Measurements and Scale Calibration Laboratory (TAMSCA) dedicated to the training in mass/volume aspects for nuclear accountability. For the TAMSCA laboratory advanced training courses have continued for Russian personnel at Ispra. These Russian participants will become the trainers for Russian trainees utilising the TAMSCA laboratory in Obninsk to demonstrate the methodological approach of tank calibrations and tank monitoring. Training courses have also been carried out for ESD inspectors with IAEA participation at Ispra.

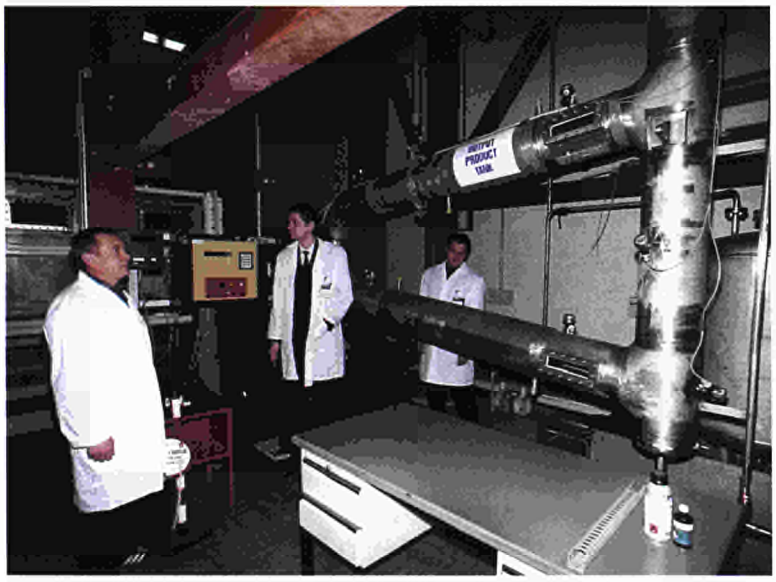


Figure 8.1: Russian participants in a mass/volume training exercise on a 'D'-shaped output product weighing tank of TAME.

Non-Destructive Assay in the PERLA laboratory

The Non-Destructive Assays (NDA) related Safeguards activities are run in the PERformance Laboratory (PERLA). PERLA is a unique, internationally recognised European facility housing an extensive collection of well-characterised nuclear reference materials and instrumentation. NDA systems, methods and techniques are characterised, validated and calibrated in PERLA and training courses take place.

In 1998 two international workshops were held: Advanced Technology for Safeguards Training, and Quality Requirements in NDA Measurements whose proceedings are in print.

Safeguards authorities continue to show an increasing interest in absolute measurements to determine the amount of Plutonium. An important part of the activities are therefore concentrated on the application and implementation of the neutron correlation technique and calorimetry.

Neutron correlation technique

author: B. Pedersen

The Compteur Neutronique de Rebuts (CNR) is a new instrument designed and constructed by ISIS. During 1998 the CNR commenced operation as a safeguards instrument for mass balance control of MOX fuel pellets in a European MOX fuel fabrication plant. Prior to installation in field, the instrument was commissioned by the European Safeguards Directorate (ESD) following substantial tests in PERLA.

The CNR is specifically designed for plutonium mass assay of scrap MOX fuel pellets. Large containers of rejected fuel pellets, destined for recycling, are assayed in the CNR before shipment from the plant. Particular measurement problems arise due to the large mass of fissile material in such MOX fuel containers. In the CNR typical containers neutron count rates can be as high as 400,000 s^{-1} due to spontaneous fission of fertile Pu isotopes. An absolute Pu mass determination, based on the analysis of neutron signal multiplets, is only possible at such count rates due to the favourable physical parameters of the CNR, and the application of the analytical dead-time correction developed at ISIS.

The CNR was actively used during the physical inventory verification (PIV) campaign in the plant. A series of MOX containers from the plant inventory were assayed in collaboration between ESD and ISIS staff. Although important dead-time corrections were applied (up to a factor of 3 for triplet count rates) deviations between the declared and the assayed mass of plutonium were only about 2%. The deviation of the sum of all measurements was less than 1%; this deviation was attributed to the uncertainty of the analysis parameters.

Calorimetry

author: M.I. Thornton

Calorimetry is a technique for measuring the thermal power of heat producing samples. It is a non-destructive technique that is independent of sample form, chemical composition or the presence of other non-radioactive materials. It functions by maintaining an isothermal enclosure in the thermal element whereby the temperature profile of the calorimeter is kept constant by electrical heaters: the base power. Following insertion of the heat bearing source, the reduction in the applied electrical power required to preserve static temperatures is a measure of the decay heat rate.
The IAEA is required to perform an initial physical inventory verification on plutonium, surplus to the American nuclear weapons programme, that is coming under international safeguards. During this initial inventory, the IAEA wish to assess the degree of homogeneity of plutonium oxide powders contained in the item. If the material is not homogeneous, several samples from one item have to be sent to the IAEA's analytical laboratory at Seibersdorf (Austria) for analysis and ultimate disposal. If it can be demonstrated that the material is homogeneous, only one sample will have to be sent which significantly reduces the burden of shipping, analysing and disposing of Plutonium.
As part of a collaboration agreement with the IAEA a series of tests were performed using an isothermal calorimeter and PERLA plutonium standards, to demonstrate the viability of calorimetry in the assessment of homogeneity in plutonium oxide samples.

The material used for the tests was PERLA plutonium oxide powder, containing approximately 71% plutonium 239, and was of a similar physical configuration to the items to be measured in the United States. The data was analysed using an equilibrium power prediction algorithm to reduce measurement times. The algorithm, based on the use of an exponential fitting procedure to estimate the thermal power of sources when the source and calorimeter reach thermal equilibrium, provides two estimates: an initial prediction and an equilibrium fit. The time for the calorimeter to produce a prediction, which itself was typically within 5% of the final value, was in the range 82-103 minutes. The time required for the equilibrium value was between 164-190 minutes. Even though the thermal powers of the samples were low, with an expected accuracy of 5%, measurements of five plutonium oxide standards gave an accuracy of 0.5%. Following the successful completion of these tests, the IAEA asked ISIS to provide functional specifications of an instrument that would be able to approach a level of precision better than 0.2%, with heat outputs of only a few mW. As a result, a new small sample calorimeter has been specified by ISIS and is under construction by an external company (Antech Limited, UK).

Unattended measurement station for low enriched Uranium fuel assemblies

authors: J. Gonçalves, J. Löschner, P. Schillebeeckx

In the second half of 1998, the Unattended Measurement Station (UMS) for fresh uranium fuel assemblies (BWR and PWR), was installed at the ABB LEU fuel fabrication plant at Vasteras (Sweden), Figure 8.2. The UMS was developed and tested at ISIS under the support program to DG XVII (Euratom Safeguards Directorate) and provides a neutron coincidence counting measurement (a neutron collar) and optical identification of the assembly. The measurement station is designed to function in a fabrication facility as a safeguards instrument providing unattended service for months without the intervention of a Euratom inspector. The instrument is integrated into the production flow in the facility and will be operated by the facility personnel. For this reason, the UMS was manufactured according to the requirements of the EEC 89/392 Machine Directive and made compliant with the standards EN 292 1/2, EN 394 and EN 60204-1.
Once the assembly is loaded into the Unattended Measurement Station (UMS), the measurement and identification are carried out automatically by the system without any intervention of the facility personnel. The system has the facility to transmit measurement results via modem. Measurement results generated in automatic mode are based on automatic background and performance monitoring. The automated UMS can be used in a safeguards approach in which the operator allows it to verify up to 100% of the production. The safeguards inspector has to simply configure the instrument for the type of verification required during the unattended period. The installation of the UMS at ABB is to test the impact of this safeguards approach on the production flow in real manufacturing conditions and to verify the precision of the measurements.

At the end of 1998, fuel elements of an ABB PWR production campaign were measured under simulated safeguards conditions. Calibration curves for PWR measurements had been prepared in the PERLA laboratory using a reference 'mini assembly'. Two different types of assemblies were measured at ABB and measurements were performed in both multiple position and scanning mode. These measurements showed that the quality of measurements performed by the UMS was equal to that of manual performed NCC measurements. During these measurements the impact on production flow was minimal and it suggests that 100% verification is technically possible.

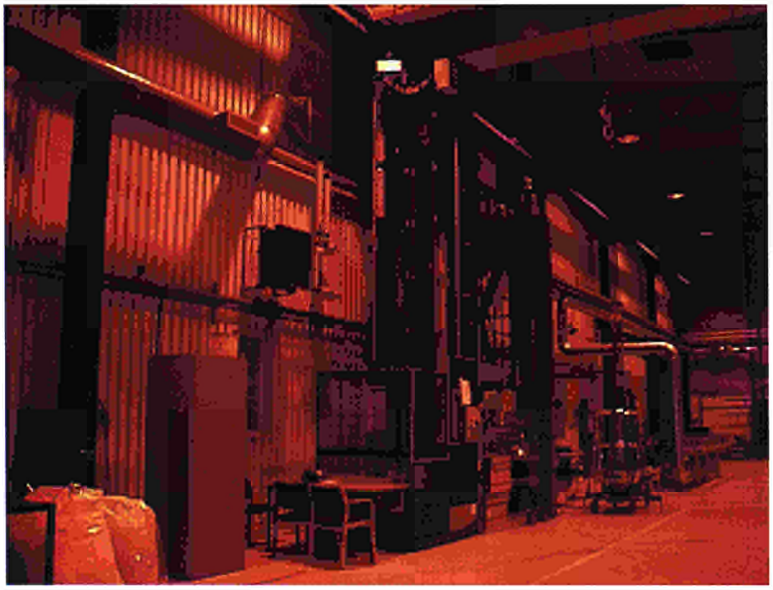


Figure 8.2: The Unattended Measurement Station (UMS) for fresh Uranium fuel assemply installed at ABB Sweden.

Gamma spectrometry

author: R. Berndt

Another ongoing activity at ISIS is the precise characterisation of gamma spectra of Cadmium Zinc Telluride detectors. These detectors are more and more used for safeguards because they have a much better energy resolution than NaI detectors and they do not need liquid nitrogen cooling as the Ge detectors. The precise description of the gamma radiation peaks is necessary for safeguards applications as the interpretation of gamma spectra measured under water to check spent nuclear fuel, or the interpretation of uranium and eventually plutonium gamma spectra.
As in previous years, training courses for EURATOM inspectors in the field of gamma spectrometry were carried out. The training concerns the gamma spectrometric measurement of the Uranium enrichment both with NaI detectors and with High Resolution

* MTR - Material Testing Reactor - a water-cooled thermal reactor in which the fuel assemblies consist of an array of aluminium clad plates containing a highly enriched uranium-aluminium alloy.

** TRIGA - a water cooled research reactor normally fuelled with enriched uranium-zirconium hydride in form of a solid homogeneous fuel rod, clad in zircalloy.

Ge detectors, and the measurement of the isotopic composition of Plutonium. All the training is now done with the newly introduced computer controlled and miniaturised MCA-166.

New Gamma scanner for Material Testing Reactor (MTR) fuel assemblies

author: U. Weng

Under the support program to Euratom Safeguards, ISIS is developing an improved gamma scanner system intended for ^{235}U content and active length verification of fresh MTR* fuel assemblies, TRIGA** assemblies and single fuel plates. The instrument is intended to replace the system that has been used by the Euratom Safeguards Directorate (ESD) in the CERCA fuel assembly fabrication plant at Romans sur Isère (France) since 1995. Its measurement is based on comparing an unknown fuel element with a reference fuel element of identical geometrical configuration. For each element, the technique consists of measuring the emission count rate of ^{235}U and the transmission count rate of a ^{75}Se source. Ratio comparisons are made between the two fuel elements in terms of both emission and transmission count rates at the relevant photopeaks. These ratios are expected to be 1 for a satisfactory result. If the ratio comparisons are not as expected, an analytical expression allows for quantification of the ^{235}U content. Taking into account the measurement experience using the earlier gamma scanner, an advanced instrument is being designed and built. The main modifications consist of the introduction of a fully computer controlled multichannel analyser, new computer hardware and the WinNT 4.0 operating system. This offers the inspector optimised user handling and enhanced performance.

Surveillance and remote monitoring

authors: J. Goncalves, V. Sequeira, F. Sorel, P. Guilmain

Remote data transmission

Public Communication Networks constitute a cost-efficient way to achieve the transmission of data between power plants and the headquarters of Safeguards authorities. Encryption is mandatory considering the confidentiality requirement in Nuclear Safeguards. Figure 8.3 describes a general-purpose data encryption architecture that was set-up to meet specific requirements for transmitting Safeguards data over public communications network, namely ISDN. Local trials were performed using remote surveillance and video conferencing applications. A package for monitoring the communications performance of ISDN-based applications was also developed (see Figure 8.4).

Laser surveillance and video authentication

A novel surveillance system was developed using a laser range finder. The system requires no illumination for detecting changes in the environment. Changes are detected by analysing in real time laser generated distance profiles. The laser surveillance system can operate as a stand-alone device or combined with conventional video surveillance systems. Once an event is detected a series of video snapshots are stored for later reviewing.
A study evaluating the needs of authentication of scenes under surveillance, i.e., in-front-of-the lens, was undertaken. Following this study a laser surveillance system was set-up to provide scene authentication as a complement to conventional video surveillance systems. Figure 8.5 illustrates the laser surveillance system, and the detection of small changes in the environment.

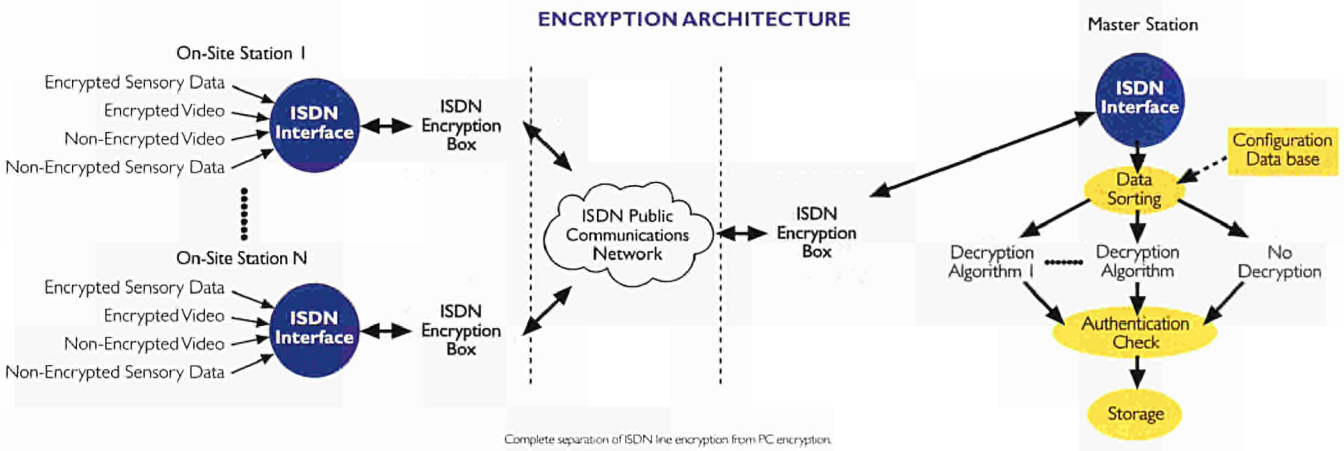


Figure 8.3: Encryption for remote data transmission applications in Safeguards.

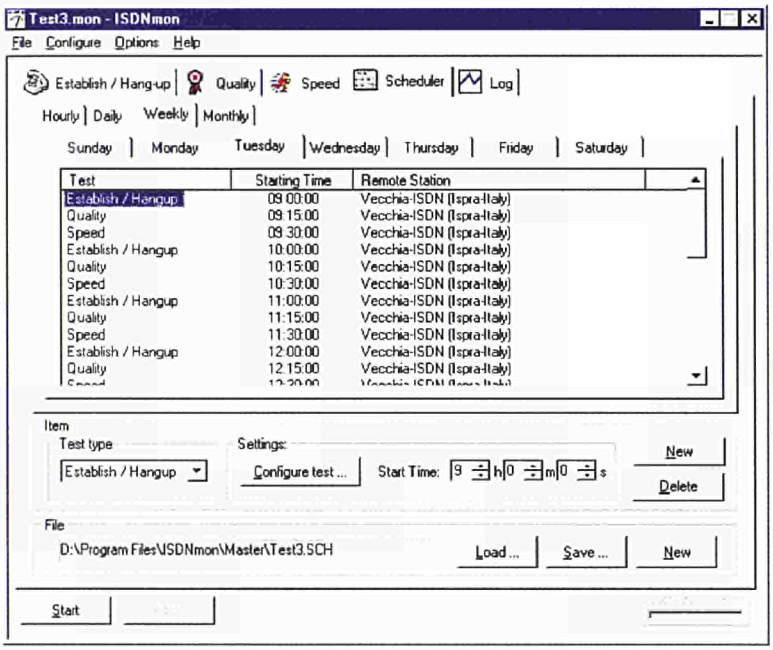


Figure 8.4: ISDN communications performance monitoring.

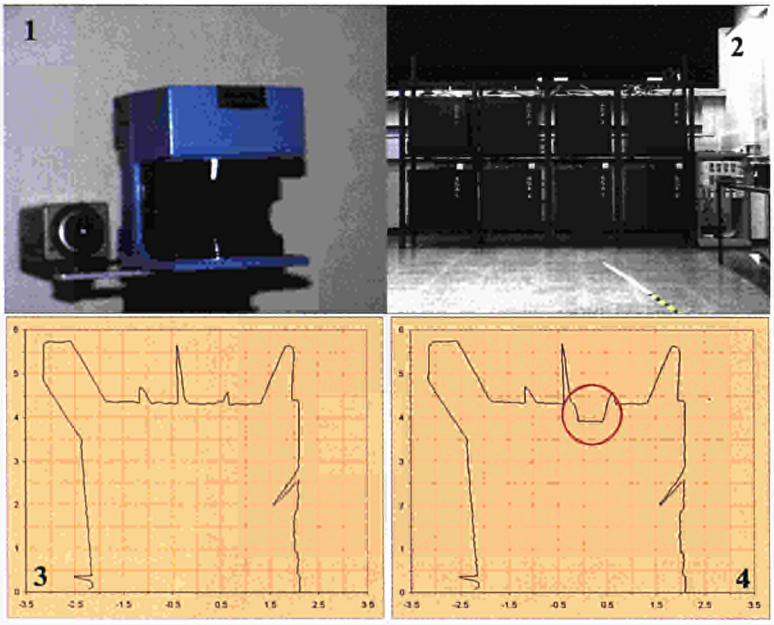


Figure 8.5: Laser surveillance system.

Digital video surveillance on local network

This project deals with the design and integration of modular and safeguards oriented systems based on of-the shelf available technology components. The explosive evolution of technology in digital video, data processing and transmission creates a consumer market of products, some of which may be suited for safeguards applications. One system was set up integrating in an embedded PC the video grabber, local storage and Ethernet connection. Several of these camera stations can be connected over the network to a central review station. Reliability tests are going on.

Functional testing of surveillance systems

It is important for the safeguards authorities to test systems in simulated field conditions before performing real field tests in the plant. JRC installed in a laboratory a functional test environment according to the specifications of EURATOM. The scope of this laboratory is the testing of the functions and the performance of surveillance equipment. The first system under test was a thermal infrared camera with high sensitivity to detect the presence of nuclear material in containers. The tests documented the possible operation range in safeguards applications for this type of equipment. The second system was a digital compact video surveillance system, designed specifically for safeguards by industry. It performs many functions including scene change detection and image compression. A complete documentation on the performed tests related to the first group of functions has been achieved. Useful results concern the correct configuration of some parameters for specific applications. The testing of the second group of functions is under way.

A new detector and surveillance dystem (SYCLOP)

The detection is mostly based on moving intruders (heat sources) or imaging of a defined space around an object.
The problem is to monitor at distance a defined zone with the possibility to move within an unmonitored portion of that same room.This is a fundamental limitation of the technology being used. Numerous video systems are currently used in Safeguards to:

- assure the continuity of knowledge of nuclear material
- survey defined locations, parts of locations or object themselves
- control access to secured locations.

These technologies can be technically complex. Their review-time are long and generally quite expensive. This paper presents an "innovative product" able to associate a visual image with every alarm event.
The originality of the new surveillance system called SYCLOP (SYstem of Control of Locations and Objects

by Parabola) is that it is based on heat flux technology using thermal balance time-variations, rather than infrared analysis, as a means of detection.
A heat flux radiative sensor is used to give information on the energy gap between an object and its environment by sensing thermal variations. A parabolic mirror focuses radiation from a zone to be surveyed onto a small planar sensor. As innovative technology, the advantages of this system can be summarised as follows:

- *Surveillance with possibility to move in the same room:* SYCLOP allows the user to monitor at distance a defined zone with the possibility to move within an unmonitored portion of that same room.

- *Combination Camera/Detector: short and efficient recording.* The combination of detector and video camera offer the possibility to have a visual image associated with every alarm event, so the system is able to discern false alarms from intruding events.

- *Selective surveillance: gain by exposure and inspection time.* The system's ability to protect specific objects, rather than whole room, allows to follow detections and to select alarms.

- *Multisensor: fire, smoke, ΔT° detection...* The system offers much greater flexibility than current passive surveillance systems without being necessarily more expensive.

- *Characteristics and accessories:* Even if the system by itself is simple, it provides a wide range of possibilities:
  - a maximum of 64 sensing elements can be relayed to a central base station for a full-featured installation. A set of circular and rectangular parabolic detectors, selected according to forms of volume to be monitored, must be strategically distributed around the areas to be covered.
  - Parabolic detector:
    - autonomous
    - flexibility in adapting to the field of view by means of a angle regulator
    - detection distance 1 to 15m
    - wide thermal detection range (at the same time from -70°C up to +1000°C)
    - useful day/night
    - high sensitivity 40mV/W/cm^2
    - low thermal resistance (<1000Ω).
  - Central base station in stand-alone mode:
    - possibility to attach a Personal Computer
    - software utilities for analysis and notice of alarms
    - weekly battery backup
  - Closed Circuit TV cameras support:
    - CCTV technology is used as an additional video support
    - a visual image is associated with every alarm event, so false alarms can be distinguished from real intrusions.
  - Two modes of communication:
    - possibility of "master-slave" configuration between sensors
    - central station by fibre-optic or RF links with encryption.

79 Semi-autonomous monitoring and robotics technologies (SMART-2)

ISIS contacts: J. Gonçalves, V. Sequeira, F. Sorel

The objetives of SMART-2 is to train young researchers in the field of Robotics Technologies, including monitoring and surveillance applications.
During 1998, the research work shared the common theme of environment mapping, and progressed in the following projects:

- *Development of a laser based surveillance system*

- *Learning robot capable of building the map of dynamic environments*

- *Development of a prototype of a handheld device for acquiring 3D data in view of virtual and augmented reality applications, as described in Figure 8.6.*

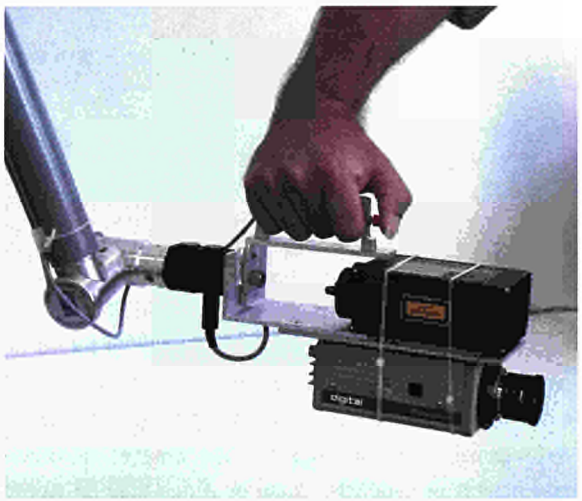


Figure 8.6: Prototype handheld device for acquiring 3D data.

Sealing and identification techniques laboratory (SILab)

author: B.C. d'Agraives

During 1998, the SILab activities were mainly an extension of those of the previous year (1,2,3). But a particular effort was also devoted to new tasks as a result of external demands (4,5,6,7).

1. *Support and assistance to EURATOM Safeguards Directorate (ESD) and IAEA at the THORP Reprocessing Plant of Sellafield (UK).*
   ISIS has been called several times in Sellafield where its MK4-R Sealing-Bolt Technology is in routine use since 1992 for the Safeguarding of Spent Fuel containers called MultiElements Bottles (MEB) and supports EURATOM and IAEA inspections. During 1998 ISIS installed and tested two software deliveries: the new Seal DB 97 and DAP5 programs, and trained the inspectors. Moreover, in the large Pond Handler of the THORP storage pond, ISIS helped inspectors to place or change about 100 sealing-bolts onto MEBs and checked more than 400 of these.
2. *Development of a new sealing-bolt for BNFL MEBs.*
   With the experience gained on site and because of a new MEB lid design (type: 1196) ISIS' SILab has designed, manufactured and tested a new "MK4-T" Sealing-Bolt which essentially occupies a smaller area on the lid (smaller diameter) but also incorporates a brand new and simpler mechanism for the breakage of the so-called "Integrity link", the part which is broken while a sealing-bolt is loosened and unscrewed. This type, which would fit the new lid design, is easier to use, simpler and cheaper to manufacture, and could be produced instead of the standard MK4-R.
3. *Experimental approach of a new optical identification technique using HeNe laser images.*
   SILab has completed a feasibility study on a new technique aimed at identifying the objects by means of their specific roughness texture. The equipment has been selected, ordered and installed allowing a first series of tests using the so-called "Speckle" Surface Interferometry Images obtained with Helium/Neon laser light. The in-situ repeatability of this particular imaging process has been obtained. SILab is to obtain the repeatability after moving the "measured" item.
4. *Exploration of potential customers abroad.*
   A demonstration was organised in the USA by SILab together with JAI (a bureau specialised in the American Safeguards). Several utilities or container makers (Framatome Inc., Westinghouse, Transnuclear, BNFL, TN West, Holtec, NAC) were visited and presented with real-scale prototypes of Safeguards' sealing systems from SILab. At least two (Westinghouse and Holtec) wish to collaborate or contract with ISIS.
   At the ENC 98 Nice (France) exhibition, several prototypes of various applications of ultrasonic seals were presented. This led to interest from organisations such as ABACC, the (Safeguards) Brazilian-Argentina Agency for Nuclear Control and Accountancy, and the Korean Safeguards Agency (KAERI), for the possible development of an ultrasonic cap seal for spent fuel storage of the CANDU reactor type.
5. *Proposal for ad-hoc ultrasonic sealing systems for various specific applications.*
   SILab has studied and built a prototype for a system which might be adapted for the safeguarding of the UF6 drums used by the Brazilian Navy and which is to be placed under the ABACC control.
   It has also built a prototype for a special locking system which could be used for the Safeguarding of HOLTEC (USA) transport containers.
6. *Development and implementation of a new and special ultrasonic identification technique.*
   An "Ultrasonic Identification System for Items through Special Internal Marking" has been developed. A performing prototype for the identification of an actual PWR fuel bundle upper-end has been manufactured and its related operating electronic hardware and software has been developed. This new technique allows sufficient

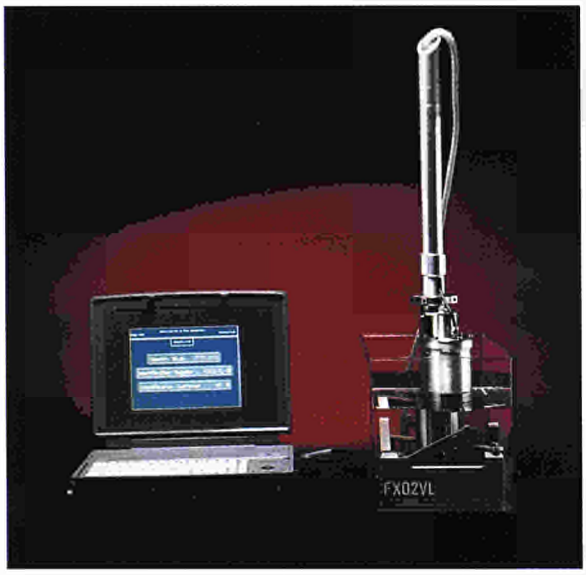


Figure 8.7: A new ultrasonic system allowing the independent in-situ underwater identification of a PWR (Pressurised Water Reactor) fuel bundle. A specific immersed reading device "reads" a special insert and provides in few seconds the bundle serial number and other associated information (patent pending).

information to be embedded in a small volume of stainless steel (1 or 2 cubic centimetres) thus generating around 80,000 to 2,000,000 different numbers, according to the size. The capacity of producing these inserts has continued as have the ad-hoc reading instrument and the related algorithms and software. This technique, which enables one to "read" an item in few seconds underwater, might have a broad application range, not only in the nuclear field but in all circumstances where the reading of serial numbers may prove difficult. A Patent Application procedure has commenced.

7. *Preparation of a long term third-party contract with the Japanese nuclear industry.*
   A two-year third-party contract was negotiated with two Japanese fuel manufacturers: Hitachi and Toshiba. This contract will enable the development by SILab of a Fuel Assembly Ultrasonic Sealing Technique (FAUST) specific of the Hitachi and Toshiba BWR MOX fuel design. The proposed ultrasonic seal would respect the strict limits imposed by the Japanese design and be a "full cycle" seal to be installed at the MOX Fuel Fabrication Plant (most probably in France, Belgium or U.K.) and would be verifiable by inspectors at any step until the final storage or eventual reprocessing.

Transponder technology in Safeguards

authors: C. Korn, G.Azzalin

A new, low cost, simple to use electronic technology has been developed that provides new opportunities for the sealing and tagging in Safeguards. This new technology is based on passive transponders. The transponder has no battery, its dimensions vary from millimetres to centimetres and it is activated by a radio-frequency field generated by a portable or stationary reader returning its unique 64 bits identification code to the reader.

The technology has been tested on U drums (Figure 8.8) to automatically identify those drums entering and leaving storage rooms, resulting in a fast inventory with a minimum of errors and minimising the inspector's exposure to radiation.

Some performance studies were conducted and the reading efficiency of the transponder was 100% when the drums were 25 mm apart. The reading distance of these transponders, with their specifically designed reader is about 6 cm with a reading angle of 45°.

As this technology is used for Safeguards applications, some irradiation tests were conducted to guarantee the correct operation of the transponder. Various transponders were exposed to a Co-60 source up to 780 Gy (by 10 Gy steps). No problem occurred, the code was read without any alteration and no physical damage was observed. The test is still running and will continue up to the breakage of a transponder to study its life-time when submitted to radiation.

A second application developed with passive transponder is the identification of plastic sample bottles used in reprocessing plants. Two solutions are proposed:

- The bottle is tagged by attaching a flexible transponder onto it (left-hand part of Figure 8.9) if an attempt is made to remove the flexible transponder from the bottle, the coil breaks and the identification code cannot be read.
- The tagging is inside the bottle cap where the transponder is attached inside it (right-hand part of Figure 8.9) once the bottle is closed, the transponder cannot be removed without altering the cap.

A third application is the development of a new seal replacing the Copper Brass seal. This new seal called Passive Transponder Seal (PST) is based on the same principle as the Copper Brass seal: it is a wire seal.

Figure 8.8: Tagging of U drums. The reader is on the left drum. The antenna – attached to the reader – records the tag on the right –hand drum by generating a low radiofrequency signal.

Figure 8.9: View of some sampling bottles identified by transponder. On the left, the cup (with transponder inside) can be attached to the sample bottle that could also have a transponder as shown. On the right is a sample bottle with a transponder also in its cup.

Instead of putting two lead drawings inside each cap, one passive transponder is placed inside each one with a mechanical integrity of the seal that was increased as well as a certain mechanical integrity of the transponders themselves.
The installation of the PTS seal in field is as simple as for the Copper Brass using a wire. When installed, a portable reader easily reads the identity of each cap. Each identification number is then stored and can be transmitted to headquarters or compared with a reader-resident database. Specific software is being developed to fulfill all the user's requirements. Based on the PTS technology, it is no longer necessary to replace the installed seal as often as the Copper Brass ones.
DG XVII (Energy) in Luxembourg is testing 50 seals and another 50 are to be evaluated by the IAEA.

80 Quality control of nuclear waste packages with a Compton suppression and Ge-telescope detection system

ISIS contact: P. Schillebeeckx

A passive Gamma interrogation technique based on a combination of Compton suppression and Ge-telescope techniques is studied to improve the nuclear industry quality control of nuclear waste packages and waste forms. The system is especially designed for accurate activity determination of actinides in presence of high activities of gamma-emitting nuclides (i.e. fission products). The use of a combination of a Ge-telescope, consisting of a planar and a coaxial detector, with a guard detector will improve detection limits and accuracy and will result in shorter measurement times.
The realisation of the project is mainly based on experimental work with existing equipment and facilities. Measurements were performed on simulated and real waste packages. The total detection system, including electronics, data acquisition hard- and software, is an existing ISIS prototype. The measurements on simulated waste were performed at ISIS and VTT. The measurements on real waste drums were performed at VTT and CEA, two institutes responsible for research on quality control of waste packages in their corresponding countries. In parallel with the experiments, Monte Carlo calculations were performed using MCNP, FLUKA and TRIPOLI to verify the experiments and as a guide for the definition of the analytical procedures.

81 Round robin test for non destructive assays of 220 litres radioactive waste packages

ISIS contact: R. Berndt

From 1996 to 1998 ISIS participated to the project "Round Robin Test for Non Destructive Assays of 220 Litres Radioactive Waste Packages". Ten European institutions participated with non destructive measurements of waste drums.
At ISIS measurements were done using both a passive neutron technique and a newly developed method for the gamma scanning. The neutron method - i.e. the "Waste Drum Monitor" - measures the content of fissile material. The neutron pulse train was analysed with an ANTECH model 1000 frequency analyser. The method, developed at ISIS, applies interpretation models for neutron signal multiplets. The gamma scanning method was developed for this project. It is a Two Collimator Rotational Scanning. One measurement is done in the traditional open geometry, and a second one with a slot collimator which lets the detector "see" only the central part of the rotating drum. The measured radiation intensities of these two measurements are then added (or subtracted) with special weight factors taking into consideration the drum mass, diameter and the energy of the gamma radiation. By this means the method derives, much better than other methods, the activity of gamma radiation sources in the central part of the drums. In addition, the method results in smaller measurement errors than the conventional segmented gamma scanning.
By the end of 1998, all the results of measurements on 18 waste drums from the ten partners were summarised. They characterise the state of the art of the typical measurement equipment for radioactive waste drums and show, which uncertainty range has to be accepted by operators and authorities for this type of measurements.

Conservation of cultural heritage

editors: A.C. Lucia, M. Zurn

The conservation of cultural heritage remains an important research interest within ISIS. This is not only backed up by the politics of the European Commission but it is also manifested in the fact that the protection of cultural heritage is for the first time explicitly mentioned in the JRC Programme within the Fifth Framework Programme starting in 1999. ISIS is contributing to the Conservation of Cultural heritage both by developing new, innovative technologies and by customizing and transferring to the field of works of art techniques and methodologies from other application fields.

ISIS deals with research, development and application of optic techniques for analysis, diagnosis and monitoring. A further line of activity is in the field of storage and dissemination of information on cultural heritage for valorization and preservation. The objective of these activities is to contribute to innovation and improvement of diagnosis techniques (which are at the basis of any conservation and restoration interventions), to strengthen knowledge sharing and dissemination of best practices.

During 1998, the Cultural Heritage work at ISIS was split up into four activity lines:

digital photogrammetry; laser interferometric methods (mainly improvement and application of the Electronic Speckle Pattern Interferometry-ESPI); smart composite materials for consolidation and monitoring; information collection and dissemination (mainly within the EC Structural Funds - Basilicata project: an example of a direct co-operation with and technology transfer to a region of the EU).

Another relevant activity carried out at ISIS is focused on the safety of historical buildings (see Chapter 5: Safety of civil engineering and cultural heritage structures).

Digital photogrammetry

author: M. Zurn

Photogrammetry is a standard technique used in the conservation of cultural heritage to document the state and the shape of three-dimensional (3D) objects such as monuments, buildings, and statues. With this technique it is easy to retrieve input data: the object is photographed and a topographic measurement of a few reference points is made in case there is a need to relate the object to external coordinates.

Digital differential object models (DIMs)

The ISIS Photogrammetry Laboratory is equipped with all the instrumentation needed to perform close-range (terrestrial) surveys and to analyze aerial photograms as well. New photogrammetric procedures were developed, implemented and tested (for an area in the Agrigento surroundings, Sicily) for the analysis of aerial photograms for:

- detecting and documenting morphological changes like excavations (as in Agrigento that is also rich of archaeological sites);
- detecting building variations of housing stock;
- detecting waste deposits.

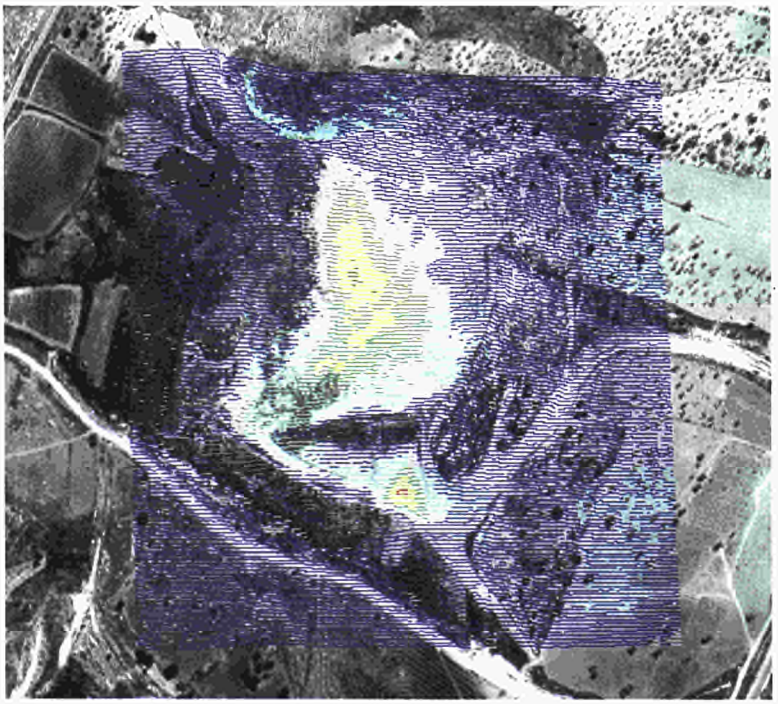


Figure 9.1 Aerial photo of the region of interest with overlayed graphics. Blue zones denote unchanged elevations, red zones denote elevation growths (waste heaps), other colours denote excavation zones.

For the application on the Agrigento area two sets of photographs of an area of few square kilometres were available, respectively taken in 1992 and 1987 (cartographic routine flights). In this study, the relative changes in surface morphology were analysed via the creation and manipulation of so-called DTMs (Digital Terrain Models). Differential Models (DIMs) were then created and relevant tools for the calculus and for the visualisation of the DIMs were developed and integrated in (or interfaced to) the commercial photogrammetry software already available (Leica-Helava LH DPW) as shown in Figure 9.1.

The aerial project gave satisfactory results even though the input data did not come from ad hoc survey campaigns. Difficulties incurred were:

- the two flights in 1987 and 1992 were performed at considerably different heights resulting in different photographic scales;
- the two flights were performed during different seasons of the year resulting in a base noise originating from the different states of vegetation;
- the absolute co-ordinates of landmarks had to be taken from normal maps (limited "Ground Control").

The positive results were obtained using the common orientation of photograms from different times; a careful identification of non-variant reference points was necessary.

Apparently, the DIM technique can be extended to close-range photogrammetry where the above mentioned problems are much easier to suppress than in aerial photogrammetry because the photogrammetry operator has a direct influence on the taking of the photographs. Preliminary studies were performed on a masonry sample that has been degraded via exposure to moisture during a 3-month (winter) period. The object was photographed before and after winter and the respective DTMs were created. The resulting DIM was calculated, too, and showed promising results.

Close range photogrammetry studying wall degradation

Even though photogrammetry is an optical tool serving to characterise nothing but geometric information about an object this tool can be used to assist architects and restorers in the study of degradation.

A typical example is the so-called "Cascine Rosse", located in the Milan area (Italy) and constituted by

several small buildings (one of which shown in Figure 9.2) with apparently degraded wall structures. The surface of these walls was studied in detail. A typical part of such a wall was photographed with a metric camera (Figure 9.3) and a digital model was calculated based on the photographic input data (Figure 9.4). Particular software tools were written in order to characterise the wall and special emphasis placed on the study and quantification of missing mortar volumes. To achieve this, the 4-dimensional (three geometric dimensions plus a pointer on automatic correlation results) character of Standard DTMs was used; this is to say that a special pointer marked the mortar areas.
Application example: starting from the two pictures shown in Figure 9.5, the DIM analysis was performed, leading to the results clearly represented by the three digital models shown in Figure 9.6.

Figure 9.2: Cascine Rosse, Milan (Italy).

Electronic speckle pattern interferometry

authors: D. Albrecht, M. Whelan

Determination of coefficients necessary for finite elements modelling of materials used in cultural heritage buildings

Unexpected failure of building materials often are caused either by pre-existing flaws or by damages due to natural ageing mainly related to weathering. The initial crack can grow and lead to fracture. Crack propagation can be modelled once the mechanical characteristics of the material are known. It is possible to determine the mechanical characteristics of a material by observing its behaviour under loading conditions. More specifically, attention has been paid to the determination of the strain map, the stress-strain diagram and the fracture energy surrounding the propagating crack of materials used in cultural heritage buildings. Non-destructive testing (NDT) techniques are increasingly used for material characterisation and structural evaluation. Optical measurement methods like Electronic Speckle Pattern Interferometry (ESPI) technique allow a full-field analysis where crack formation and propagation in structures can be easily observed. ESPI measurement instruments have been used in mechanical tests carried out in collaboration with the Structural Engineering Department of the Politecnico di Torino (Italy). For example, the set-up used during the experiment allowed to draw up the mean strain map over the inspected area.
In the frame of the valorisation and technology

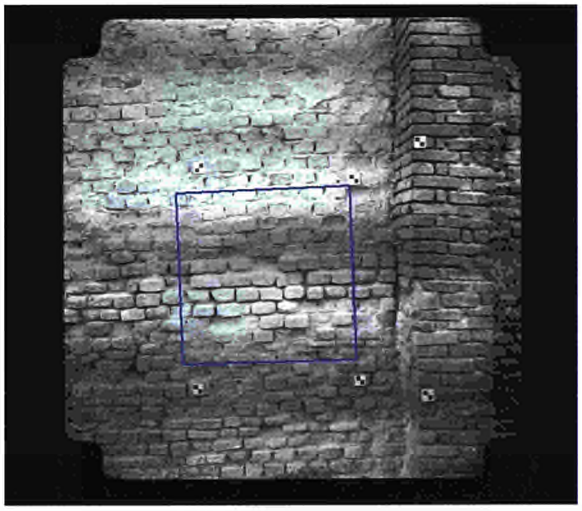


Figure 9.3: Photogramme of degraded wall structure of Cascine Rosse.

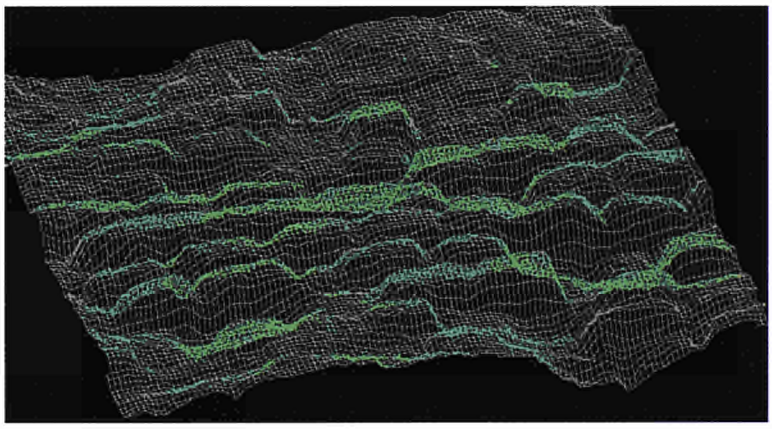


Figure 9.4: Digital Model of degraded wall structure at Cascine Rosse.

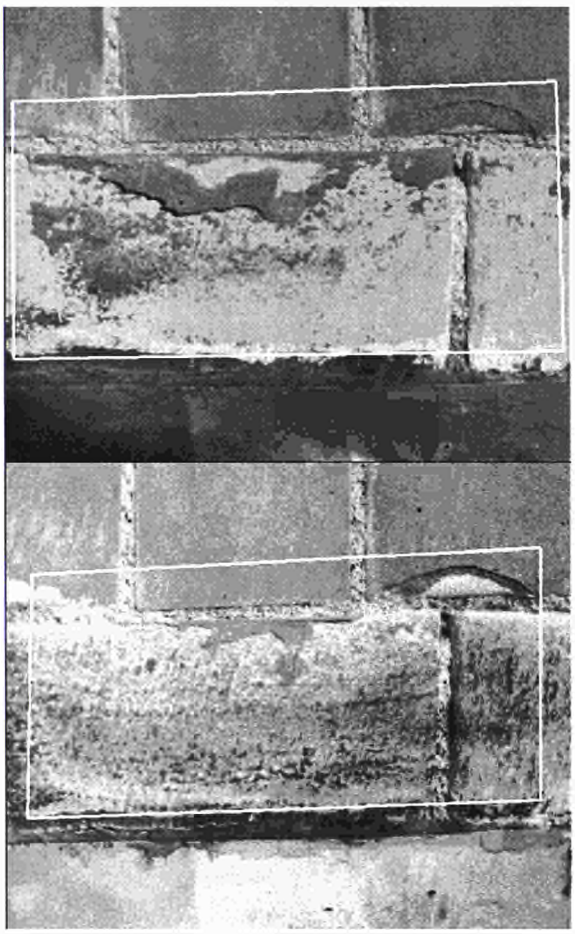


Figure 9.5: Cascine Rosse.
top: State of the wall before winter
bottom: State of the wall after winter.

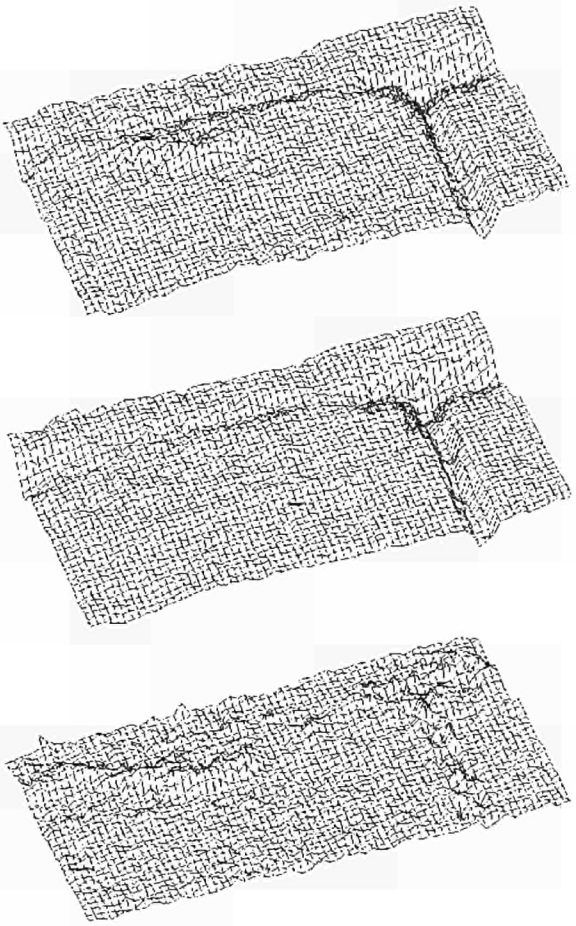


Figure 9.6: Cascine Rosse.
top: Digital Terrain Model before winter
center: Digital Terrain Model after winter
bottom: Differential Model

transfer activities funded by DGXIII (Telecommunications, Information Market and Exploitation of Research), the R&D work on ESPI technologies has enabled the ISIS Photonic Laboratories to develop several instruments, among which the double simultaneous in-plane DSPI (Digital Speckle Pattern Interferometry) prototype instrument. This is currently being tested and evaluated by potential industrial end-users (Ettemeyer-Germany, Honlet-Germany).

Diagnostics of conservation state of paintings on panel

Non-destructive optical measurement techniques are of great help to assess the conservation state of pieces of artwork. The adopted method is mainly based on visual observation of the thermal deformation of the inspected area. Measurements took place, in the "Laboratori di Restauro dei Dipinti dell'Opificio delle Pietre Dure" of Florence in Italy. The "Incoronazione della Vergine" (Figure 9.7) is in its final restoration phase. Particular care was brought to the central zone, in the lowest part where an area is missing. A new piece, a panel, whose figure is compatible with the rest of the work, was added (Figure 9.8). The restorers managed to re-compose the missing part. The layered structure of the new panel was stuck only in some places, on purpose, for ethic and restoration methodology reasons that must respect the story of the piece of artwork and insure the reversibility of the restoration intervention. The ESPI technique was there successfully used to analyse the structural behaviour of the panel; the analysis confirmed that the addition of the new piece of panel was correctly done, clearly identified the attachment points and measured the deformation field of the whole panel.

Figure 9.7: Photograph of the painting "Incoronazione della Vergine" (Lorenzo Monaco, 1414) Uffizi Gallery, Florence, Italy.

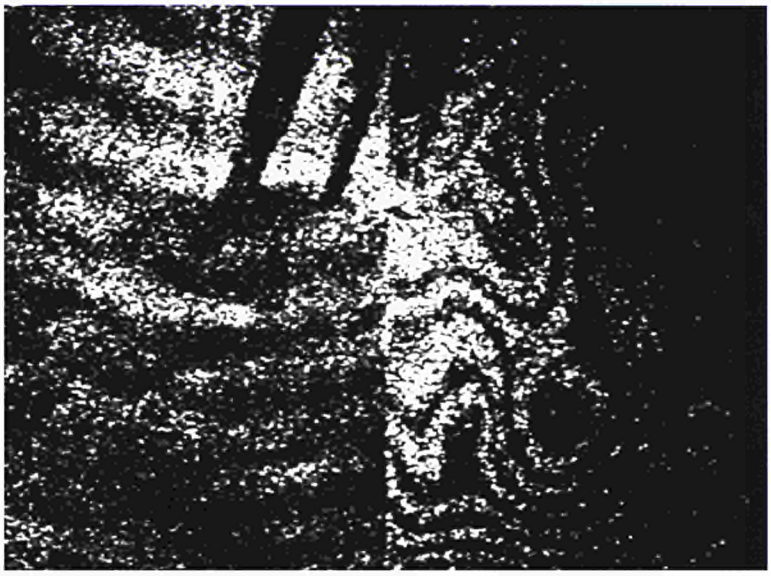


Figure 9.8: Electronic Speckle Pattern Interferometry (ESPI) of the area within the dashed frame in Figure 9.7. Note how the fringe pattern is suddenly interrupted at the junction zone between both the original and new part. On the right hand side, the support is fixed only in several points, the surface deformation is irregular.

Smart materials

author: R. Kenny

Aspects of the ISIS work in structural composites and fibre optic sensors were integrated as part of a collaborative project under the Eureka program (COMREHAB) mid-year. The project studies the application of composite material elements for low intrusion rehabilitation of civil structures. The elements contain fibre optic sensors for testing purposes and to provide a self-monitoring capability. Within this project, initial work has concentrated on identifying classes of repairs most commonly found in practice, and for those which repairs using composites are appropriate. Modelling of reinforcements using composites, including commercially available systems for comparison, has also been performed. Other issues such as fire risk, environmental factors, and cost are also being examined. Reinforcement with composite materials has been performed on a masonry structure at the ELSA laboratory of ISIS. An optical technique, Moire' interferometry, which can measure full-field strains was employed to study this reinforcement during testing.

References

[9.1] Calaon R., Forlani G., Pinto L., Zürn M. Analisi delle Variazioni Morfologiche del Territorio via Generazione Automatica di DTM. *2a Conferenza Nazionale ASITA*, Bolzano, Italy, 24-29 November, 1998.

[9.2] Zürn M., Bertolo S., Florensa M. Tecniche per Rilievi del Degrado dei Materiali con Metodo Fotogrammetrico. Conferenza Materiali e Tecniche nella Storia dell'Architettura Lombarda. Ispra, 26-28 November, 1998.

[9.3] Bertolo S. Applicazioni di Metodologie Ottiche per la Diagnosi di Edifici Storici. *Thesis*, Milan, 1998 *Cultural Heritage http://tintin.jrc.it/htdocs*

[9.4] Albrecht D. Electronic Speckle Pattern Interferometry Instruments Development, Optimisation and Applications. *PhD Thesis*, Loughborough University, UK, December 1998.

[9.5] Albrecht D. Estimation of the 2D Measurement Error Introduced in In-plane and Out-of-Plane ESPI Instruments. *Optics and Lasers in Engineering*, 11/1998.

[9.6] Lucia, A.C. I luoghi della Scienza Moderna: Contributi alla Conservazione del Patrimonio Culturale. In "*I luoghi del patrimonio*", Franco Angeli Editore, Milano, 1999.

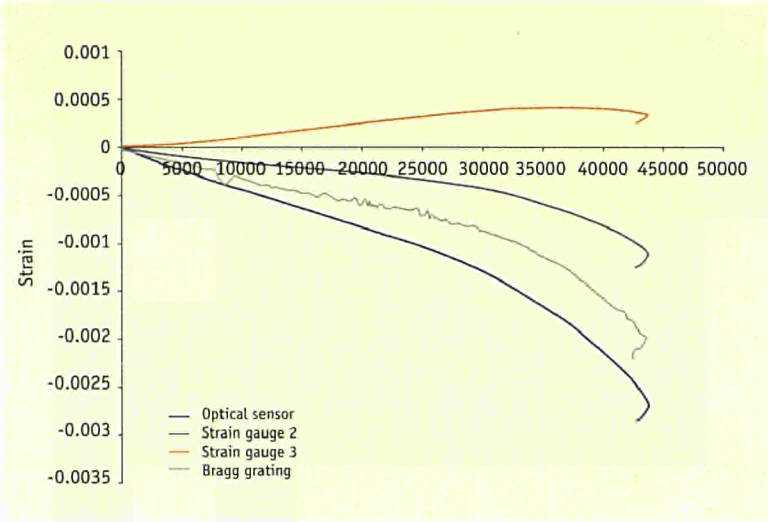


Figure 9.9: Graph of measured strain against applied load at a concrete/glass fibre reinforced composite interface. The conventional electrical strain gauges were attached to the surface of the composite, while the fibre optic gauge was embedded in the epoxy bond in order to study its behaviour. It was seen that the measurements closely followed each other, indicating good performance of the bond. With increased load failure was observed due to crushing of the concrete before debonding occurred at the interface.

Embedded fibre-optic strain sensors have also been tested. Figure 9.9 shows a graph of measured strain against applied load at a concrete/glass fibre reinforced composite interface. The conventional electrical strain gauges were attached at different positions on the surface of the composite, while the fibre optic gauge was embedded in the epoxy bond. The measurements closely followed each other, indicating good performance of the bond. With increased load, failure was observed due to crushing of the concrete before de-bonding occurred at the interface.

Information dissemination and valorisation network for Basilicata Region (Italy)

author: W. Post

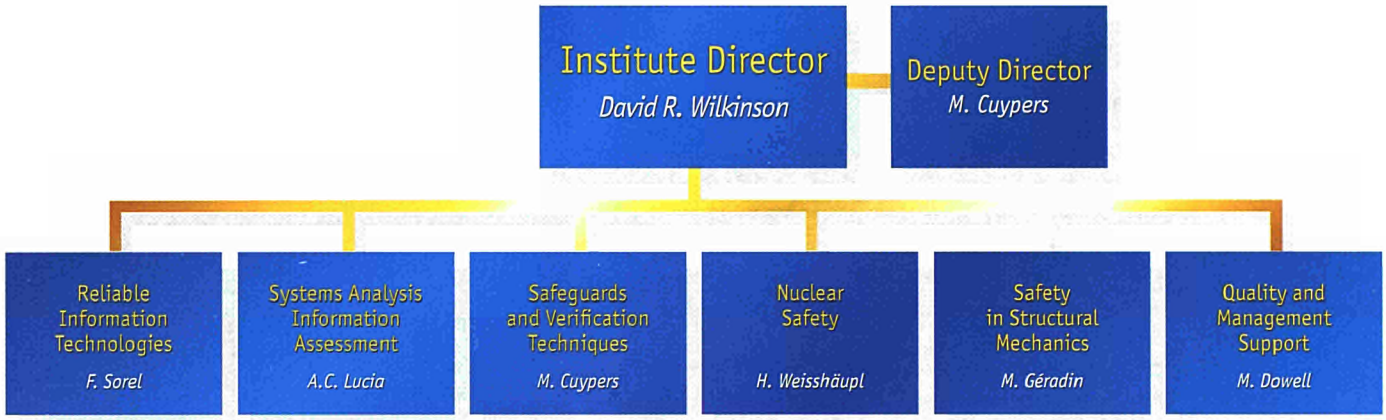
Objective of the project is to define and implement the infrastructure needed for the usage, valorisation and recuperation of cultural heritage by means of integrated resources with the goal to develop tourism in the Basilicata region. The project is a collaboration between the University of Basilicata (USB) and ISIS. The specific tasks of ISIS in this project are to develop:

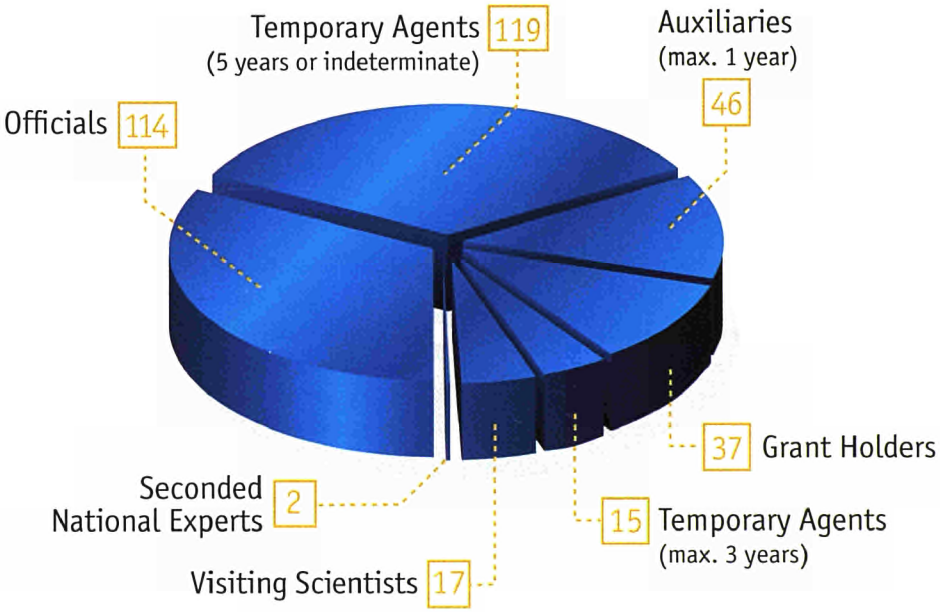
- multimedia archive that contains the data on regional cultural heritage;
- tools which allow experts in the area to create the information in this archive;
- web page generators which dynamically create HTML pages based on the multimedia archives.

The actual project started in autumn of 1997. During 1998 the development environment was set-up in a laboratory in Ispra. A tool has been developed to help define the structures of the data to be stored: the cultural resources and their related attributes, viewed in the light of the to be supported different themes. A first proposal on these data-structures has been fed back to the experts in Potenza for evaluation. In 1999 the system will be delivered to the USB after which it can be used to populate the multimedia database.

Staff

Organisation chart





Finances

ISIS customers include many sectors from European industry, regional governments and other Directorates from the European Commission. The competitive work has rapidly increased. On average over the whole period 1995-1998 more than 20% of ISIS staff work was dedicated to competitive projects. The average for 1998 was 25%. The institutional work covers he institutional support to Commission services, applied research and exploratory research, under the various themes of the European Union's Fourth Framework Research Programme.

The three tables below show details of income and work executed in 1995-1998.

Comparisons are made between achieved values and our previously defined targets.

Table I shows the new contracts which have been signed in 1995-1998
Table II shows the competitive work executed in 1995-1998
Table III shows the institutional work executed on each line of the Framework Programme

From the tables it can be seen that:

- Previously set overall targets for contracts signed and work executed have been met and exceeded
- 20% of the total work executed in the period 1995-1998 was competitive. In 1998 that figure was 25%
- Competitive contracts are well spread across a range of possible actions.

Table I: ISIS Competitive Contract Signed 1995-1998

Type of Activity	Value (Meuro) of Contracts Signed		
	Achieved 98	Target 95-98	Achieved 95-98
Competitive Support to Commission	8.48	18.00	22.35
Other Competitive Activities	2.56	3.50	5.95
Training and Mobility of Researchers	0.48	0.95	1.95
Shared-Cost Actions (50%)	4.03	6.25	11.27
Third Party Work	0.99	15.00	12.17
Total	**16.54**	**43.70**	**53.69**

Table II: ISIS Competitive Work Executed 1995-1998

Type of Activity	Value (Meuro) of Work Executed		
	Achieved 98	Target 95-98	Achieved 95-98
Competitive Support to Commission	6.94	12.0	15.94
Other Competitive Activities	1.01	1.4	1.81
Training and Mobility of Researchers	0.40	0.4	0.87
Shared-Cost Actions (100%)	5.71	7.0	12.24
Third Party Work	2.11	16.5	17.01
Total	**16.17**	**37.3**	**47.87**

Table III: ISIS Institutional Work Executed 1995-1998

Framework Programmme	1995	1996	1997	1998
Information Technologies	1.95	2.95	3.31	3.76
Measurement and Testing	7.63	5.36	3.55	3.01
Environment and Climate	8.50	5.69	7.39	7.14
Life Sciences and Technologies	0.21	0.74	1.23	1.37
Nuclear Safety and Safeguards	28.41	29.18	29.47	29.97
Controlled Thermonuclear Fusion	1.83	1.45	1.33	1.34
Total	**48.53**	**45.37**	**46.28**	**46.59**

Shared-Cost Action partners

1 Multi Site & Multi Stage Enterprises Logistic Control System (MUSSELS)
Cranfield University (GB); Fraunhofer-Institut fuer Produktionstechnik und Automatisierung (DE); ISA Systems-Entwicklung und Integration Komplexer Informations- und Kontroll- Systeme (DE); Omega Organizzazione e Metodi di Gestione Aziendale (IT); Schock & Co. (DE); Societa Pneumatici Pirelli S.P.A. (IT).

2 An Environment For Improving The Industrial Experiment Feedback Process (NOEMIE)
AcknoSoft (FR); Matra Cap Systemes (FR); Schlumberger (FR); SINTEF (NO).

3 Promoting Requirements Engineering from Current Engineering Practices (PRECEPT)
Centre National de la Recherche Scientifique (FR); Heusch Boesefeldt (DE); Integrated Chipwear (GB); Objectway SPA (IT); Philips Electronics UK Limited (GB); University of York (GB).

4 A student's Parliament vie Educational Multimedia Learning Models and Technologies (ParlEuNet)
Alcatel Bell NV (BE); Arboth Learning Technologies (BE); City College Norwich (GB); European Broadcasting Union (CH); Katholieke Universiteit Leuven (BE); Parent Association Baden-Wuertemberg (DE); Pegasus Foundation (BE); Telecom Eireann (IE); Telia AB (SE); Universidad de Barcelona (ES); Universitaire Instelling Antwerpen (BE); Universiteit Maastricht (NL).

5 ATM and Telecollaboration for Research and Education (ATRE)
Alcatel Data Networks (FR); CERN (CH); CISI (IT); GIP RENATER (FR).

6 Conceptual and computational tools to tackle long term risk from nuclear waste disposal in the geosphere (GESAMAC)
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (ES); Stockholms Universitet (SE); University of Bath (GB).

7 Reconstruction Using Scanned Laser and Video (RESOLV)
BICC (GB); INESC - Instituto De Engenharia De Sistemas E Computadores (PT); Instituto Superior Técnico (PT); Robosoft Sa (FR); University Of Leeds (GB).

8 Infoboy - Multimedial Tourist Information Kiosk (INFOBOY)
Bayrisches Staatsministerium für Ernährung, Landwirtschaft und Forsten (STMELF) (DE); ECS - Technoservice GmbH (DE); Expertise Information Systems GmbH (DE); Schwarz Computer Systeme GmbH (DE).

9 CAD Modelling of Built Environments from Range Analysis (CAMERA)
Centre National de la Recherche Scientifique (FR); Fraunhofer-Gesellschaft zur Förderung der Angewandten Forschung e.V. (DE); Instituto Superior Técnico (PT); Kungliga Tekniska Högskolan (SE); UK Robotics Ltd (GB); University of Edinburgh (GB).

10 Giving a voice to the deaf by developing awareness on voice-to-text recognition capabilities (VOICE)
Associazione Lombarda Famiglie Audiolesi (ALFA) (IT); Centro Comunicare E' Vivere (CECOEV) (IT); FBL Software House S.r.l. (IT); Institut für Hör- und Sehbindung (IHSB) (IT); Johannes Kepler University (AT); Software Solutions S.r.l. (IT).

11 Adaptive Brain Interfaces (ABI)
Fase Sistemi Srl (IT); Helsinki University of Technology (FI); Ospedale S. Lucia (IT).

12 Better integration of mentally disabled in industry
Istituto Eugenio Medea (IT).

13 Social Processes for Environmental Valuation: Procedures and institutions for social valuations of natural capitals in environmental conservation and sustainability policy (VALSE)
Universidad de La Laguna (ES); Université de Versailles Saint-Quentin en Yvelines (FR); University of Cambridge (GB); University of Lancaster (GB).

14 Urban LifestYles, SuStainability and Integrated Environmental Assessment (ULYSSES)
Consejo Superior de Investigaciones Cientificas (ES); Eidgenössische Anstalt für Wasserversorgung, Abwasserreinigung und Gewässerschutz (CH); International Institute for Applied System Analysis (AT); National Technical University of Athens (GR); Potsdam-Institut für Klimafolgenforschung e.V. (DE); Stockholm Environment Institute (SE); Technische Hochschule Darmstadt (DE); The Research Methods Consultancy Ltd. (GB); University Of Newcastle Upon Tyne (GB).

15 Integrated visions for a sustainable Europe (VISIONS)
Eidgenössische Anstalt für Wasserversorgung, Abwasserreinigung und Gewässerschutz (CH); Research Instituut voor Kennis-Systemen BV (NL); Rijksinstituut voor Volksgezondheid en Milieuhygiëne (NL); The Research Methods Consultancy Ltd. (GB); The Victoria University of Manchester (GB); Université de Versailles Saint-Quentin en Yvelines (FR); Universiteit Maastricht (NL); University of Lancaster (GB); University of York (GB).

16 European forum on integrated environmental assessment (EFIEA)
Centre National de la Recherche Scientifique (FR); Cranfield University (GB); Dr Christopher William Hope (GB); Eyre Energy Environment (GB); Fondazione Eni - Enrico Mattei (IT); Imperial College of Science, Technology and Medicine (GB); International Institute for Applied System Analysis (AT); Landbouwuniversiteit Wageningen (NL); Max-Planck-Gesellschaft zur Förderung der Wissenschaften e.V. (DE); National Technical University of Athens (GR); Potsdam-Institut für Klimafolgenforschung e.V. (DE); Rijksinstituut voor Volksgezondheid en Milieuhygiëne (NL); Risø National Laboratory (DK); Technische Hochschule Darmstadt (DE); The Research Methods Consultancy Ltd. (GB); Universität Gesamthochschule Kassel (DE); Université de Versailles Saint-Quentin en Yvelines (FR); University College London (GB); University College London (GB); University of Bath (GB); University of Bath (GB); University of East Anglia (GB); University of Lancaster (GB); University of Oxford (GB); Vrije Universiteit Amsterdam (NL).

17 Urban Transport Options for Propulsion Systems and Instruments for Analysis (UTOPIA)
AEA Technology Plc. (GB); Austrian Mobility Research - AMOR (AT); Centre D'etudes sur les Réseaux, les Transports, L'urbanisme et les Construction Publiques (FR); Energy Saving Trust (GB); Netherlands Organization for Applied Scientific Research (NL); Swedish Transport & Communication Research Road (SE); Università degli Studi di Roma "La Sapienza" (IT); Volkswagen AG (DE).

18 Management tool for the assessment of driveline technologies and research (MATADOR)
Austrian Mobility Research - AMOR (AT); ENEA - Ente per le Nuove Tecnologie, l'Energia e l'Ambiente (IT); Hogeschool van Arnhem en Nijmegen (NL); Ingenieurschule Biel (CH); Nederlandse Organisatie voor Energie en Milieu (NL); Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (NL); Netherlands Energy Research Foundation (NL); Rheinisch-Westfälische Technische Hochschule Aachen (DE).

19 Scenario-based framework for modelling transport technology deployment: energy-environment decision support (STEEDS)
AEA Technology Plc. (GB); British Gas PLC (GB); Deutsche Automobilgesellschaft mbH (DE); National Defence Research Establishment (SE); TÜV Rheinland Sicherheit und Umweltschutz GmbH (DE); Universität Stuttgart (DE).

20 Integrated computational assessment via remote earth observation system (ICAROS)
Azienda Servizi Municipalizzati Brescia (IT); Fraunhofer-Gesellschaft zur Förderung der Angewandten Forschung e.V. (DE); Institut Français de Recherche Scientifique pour le Développement en Coopération - ORSTOM (FR); National and Kapodistrian University of Athens (GR); University of the Aegean (GR).

21 Long Term Carbon Dioxide and Water Vapour Fluxes of European Forests and Interactions with the Climate System (EUROFLUX)
Agricultural Research Institute (IS); Dienst Landbouwkundig Onderzoek (NL); Faculté des Sciences Agronomiques de Gembloux (BE); Institut National de la Recherche Agronomique (FR); Risø National Laboratory (DK); Technische Universität Dresden (DE); The Swedish University of Agricultural Sciences (SE); Università degli Studi della Tuscia (IT); Universität Bayreuth (DE); University of Edinburgh (GB); University of Helsinki (FI).

22 European Terrestrial Ecosystem Modelling Activity (ETEMA)
Ecole Normale Supérieure (FR); King's College London (GB); Lunds Universitet (SE); Natural Environment Research Council (GB); Potsdam-Institut für Klimafolgenforschung e.V. (DE); University of Sheffield (GB).

23 System for Hydrology using Land Observation for Model Calibration (SHYLOC)
Aristotle University of Thessaloniki (GR); Dansk Hydraulisk Institut (DK); University College London (GB).

24 European integrated hydrogen project (EIHP)
AB Volvo Technological Development (SE); Air Liquide SA (FR); BMW Bayerische Motoren Werke AG (DE); Hamburgische Elektrizitäts-Werke AG (DE); Hydrogen Systems N.V. (BE); Instituto Nacional de Técnica Aeroespacial "Esteban Terradas" (ES); Ludwig-Bölkow-Systemtechnik GmbH (DE); Messer Griesheim GmbH (DE); National Centre for Scientific Research "Demokritos" (GR); Renault Recherche et Innovation, Regienov (FR).

25 Anaerob Digestion of Agro-Industrial Wastes - Information Network (AD-NETT)
Agriculture And Agri-Food Canada (CA); C.I.E.M.A.T. (ES); C.R.E.S. - Centre For Renewable Energy Sources (GR); Centro Da Biomassa Para A Energia (PT); Energisystemer A.S. (NO); Fachverband Biogas E.V. (DE); Herning Kommunale Vaerker (DK); Interuniversitäres Forschungsinstitut Für Agrarbiotechnologie - IFA (DE); Italian Biomass Association (IT); Netherlands Agency For Energy And The Environment (NL); Swedish Institute Of Agricultural Engineering (SE); Swiss Research Institute For Agriculture Economics And Engineering (CH); United Kingdom Atomic Energy Authority (GB); Université Catholique de Louvain (BE); University College Galway (IE).

26 A novel approach for the integration of biomass pyrolytic conversion processes in existing markets of liquid fuels and chemicals (FLASH PYRCON)
Agricultural University of Athens (GR); Centre for Renewable Energy Sources (GR); Hellenic Aspropyrgos Refinery SA (GR); Technische Universität Wien (AT); Universität Stuttgart (DE).

27 Integrated spatial potential Initiative for renewable energy in Europe (INSPIRE)
Centre for Renewable Energy Sources (GR); Centro da Biomassa para a Energia (PT); Ecofys Cooperatief Advies-en Onderzoeksbureau UA (NL); Hyperion Energy Systems Ltd. (IE); Institut National de la Recherche Agronomique (FR); Österreichische Vereinigung für Agrarwissenschaftliche Forschung (AT); Risø National Laboratory (DK); Swedish National Board for Industrial and Technical Development (SE); Technical Research Centre of Finland (FI); United Kingdom Atomic Energy Authority (GB).

28 Small-scale combined heat and power (CHP) from bio-crude oil fuelled to a stirling engine (BIOSTIR)
Agricultural University of Athens (GR); Centre for Renewable Energy Sources (GR); Hellenic Aspropyrgos Refinery SA (GR); Solo Kleinmotoren GmbH (DE); TPS Termiska Processer AB (SE); WS Wärmeprozesstechnik GmbH (DE); Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (DE).

29 Advanced mapping of European biomass activities (AMOEBA)
AEA Technology Plc. (GB); Centre for Renewable Energy Sources (GR); Ecofys Cooperatief Advies-en Onderzoeksbureau UA (NL); Institut National de la Recherche Agronomique (FR); Österreichische Vereinigung für Agrarwissenschaftliche Forschung (AT); Risø National Laboratory (DK); Technical Research Centre of Finland (FI); Universität Stuttgart (DE).

30 Assessment of the Uncertainties in Risk Analysis of Chemical Establishments (ASSURANCE)
Det Norske Veritas Ltd (GB); Health and Safety Executive (GB); Institut National de l'Environnement Industriel et des Risques (FR); National Centre for Scientific Research "Demokritos" (GR); Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (NL); Risø National Laboratory (DK); Technical Research Centre of Finland (FI); Università degli Studi di Bologna (IT).

31 Land Use Planning and Chemical Sites (LUPACS)
County Administrative Board of Södermanland (SE); County of West Zealand (DK); Fredericia Community (DK); Ministery of the Interior, Emergency Management Agency (DK); National Centre for Scientific Research "Demokritos" (GR); Risø National Laboratory (DK); Swedish Rescue Services Agency (SE); Université Pierre et Marie Curie - Paris VI (FR).

32 Thematic Network on Hazard Assessment of highly Reactive systems (HARSNET)
BASF AG (DE); CETS Institut Químic de Sarrià (ES); Chemi SpA (IT); CIBA Specialty Chemicals (UK) Ltd. (GB); DOW Benelux NV (NL); DSM Research BV (NL); Erkimia S.A. (ES); Esteve Quimica S.A. (ES); H. Lundbeck A/S (DK); Hazard Evaluation Laboratory Ltd. (GB); Health and Safety Executive (GB); Inburex GmbH Consultinggesellschaft für Explosionsschutz und Anlagensicherheit (DE); IRRADIARE Investigação e Desenvolvimento em Engenharia e Ambiente Lda. (PT); National Technical University of Athens (GR); Novartis Services AG (CH); Sanofi Chimie SA (FR); Segibo S.r.l. (IT); Solvay Quimica S.L. (ES); Stazione Sperimentale per i Combustibili SpA (IT); Technische Universität Berlin (DE); Università degli Studi di Messina (IT); Universität Hamburg (DE); Universität Stuttgart (DE); Université de Haute Alsace (FR); Universiteit Twente (NL).

33 Scientific Model Evaluation of Dense Gas Dispersion Models (SMEDIS)
British Gas PLC (GB); Cambridge Environmental Research Consultants Ltd. (GB); Det Norske Veritas A/S (NO); Electricité de France (FR); Finnish Meteorological Institute (FI); Gaz de France (FR); Health and Safety Executive (GB); National Centre for Scientific Research "Demokritos" (GR); Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (NL); Risø National Laboratory (DK); Universität Hamburg (DE); WS Atkins Consultants Ltd. (GB).

34 Advanced Design Methods for Improved Performance of Industrial Gas-Liquid Reactors (ADMIRE)
AEA Technology Plc. (GB); Basf AG (DE); DSM Research BV (NL); Enichem SpA (IT); Kemira Chemicals Oy (FI); Politecnico di Milano (IT); Praxair NV (BE); Universidade do Porto (PT); Universität Stuttgart (DE).

35 Explosion Models Evaluation Project (EME)
Battelle Ingenieurtechnik GmbH (DE); Christian Michelsen Research AS (NO); IC Consultants Ltd (GB); Institut National de l'Environnement Industriel et des Risques (FR); Statoil R&D Centre (NO); Steel Construction Institute (GB); TNO Prins Maurits Laboratorium (NL).

36 Investigations of viscous venting and treatment of releases (INOVVATOR)
Health and Safety Executive (GB); Heriot-Watt University (GB); Technische Universität Hamburg-Harburg (DE).

37 Development of Innovative Techniques or the Improvement of Stability of Cultural Heritage, in particular Seismic Protection (ISTECH)
Aristotle University of Thessaloniki (GR); ENEA - Ente per le Nuove Tecnologie, l'Energia e l'Ambiente (IT); FIP Industriale SpA (IT); Instituto Superior Técnico (PT); Università degli Studi di Roma "La Sapienza" (IT).

38 Optimization of Energy Dissipation Devices, Rolling Systems and Hydraulic Couplers for Reducing Seismic Risk to Structures and Industrial Facilities (REEDS)
Alga SpA (IT); Bouygues (FR); ENEA - Ente per le Nuove Tecnologie, l'Energia e l'Ambiente (IT); ENEL SpA (IT); FIP Industriale SpA (IT); GEC Alsthom T&D SA (FR); Instituto Superior Técnico (PT); Ismes SpA (IT); Tun Abdul Razak Research Centre (GB); Università degli Studi di Bologna (IT).

39 Improved assessment of steel buildings performance during earthquakes (STEELQUAKE)
Ismes SpA (IT); National Technical University of Athens (GR); Politecnico di Milano (IT); Université de Liège (BE).

40 Fluid Structure Interaction - High Performance Simulation For Structural Design (FSI-SD)
FEGS (GB); Norsk Hydro Research Centre (NO); Ramboll Hannemann & Hojlund A/S (DK); SINTEF (NO).

41 3D Site effects and soil-foundation interaction in earthquake and vibration risk evaluation (TRISEE)
Centro di Ricerca Sviluppo e Studi Superiori in Sardegna (IT); Consorzio Milano Ricerche (IT); Kungliga Tekniska Hogskolan (SE); National Technical University of Athens (GR); Università degli Studi di Cagliari (IT).

42 Inverse problems in structural and material mechanics (INVERPRO)
Association pour la Recherche et le Développement des Méthodes et Processus Industriels - ARMINES (FR); Institute of Fundamental Technological Research - Polish Academy of Sciences (PL); Institute of Mechanics and Biomechanics - Bulgarian Academy of Sciences (BG); Politecnico di Milano (IT).

43 Small punch test method assessment for the determination of the residual creep life of service exposed components (Small Punch)
CISE - Centro Informazioni Studi ed Esperienze SpA (IT); Institute of Metals and Technologies (SI); Institute of Physics of Materials (CZ); Materprüfungsanstalt Stuttgart (DE); Technical University of Krakow (PL).

44 Elsa Large-Scale Facility (LSF)

45 ELSA: European Laboratory for Structural Assessment Reaction Wall Reaction Wall Facility (ECOEST2)
Commissariat à l'Energie Atomique (FR); Ecole Normale Supérieure - Cachan (FR); Geodynamique et Structure S.A (FR); HILTI (LI); Institut National des Sciences Appliquées de Lyon (FR); Ismes SpA (IT); Laboratório Nacional de Engenharia Civil (PT); National Technical University of Athens (GR); Technische Hochschule Darmstadt (DE); Universidad Politécnica de Madrid (ES); Universidad Politécnica de Madrid (ES); Università degli Studi di Roma "La Sapienza" (IT); Università di Pavia (IT); Université de Liège (BE); University of Bristol (GB); University of Patras (GR).

46 Advanced Structural Dynamic Experimental Facilities (ASDEF)
Commissariat à l'Energie Atomique (FR).

47 Innovative seismic design concepts for new and existing structures (ICONS)
Consorzio Milano Ricerche (IT); Consorzio Milano Ricerche (IT); Imperial College of Science, Technology and Medicine (GB); Institut National des Sciences Appliquées de Lyon (FR); Laboratório Nacional de Engenharia Civil (PT); Technische Hochschule Darmstadt (DE); Universidad Politécnica de Madrid (ES); Università degli Studi di Pavia (IT); Università degli Studi di Roma "La Sapienza" (IT); Université de Liège (BE); University of Patras (GR).

48 Anchorages in Normal and High Performance Concretes Subjected to Medium and High Strain Rates (ANCHR)
Bekaert SA/NV (BE); Densit A/S (DK); ENEL SpA (IT); Hilti AG (LI); Politecnico di Milano (IT); University Of Patras (GR).

49 Advanced methods for assessing the seismic vulnerability of existing motorway bridges (VAB)
Centro Internacional de Métodos Numéricos en Ingeniería (ES); International Center for Theoretical Physics (IT); Ismes SpA (IT); Ministère de l'Equipement, du Logement, des Transports et du Tourisme (FR); Österreichisches Forschungs- und Prüfungszentrum Arsenal Ges.m.b.H. (AT); Universidade do Porto (PT).

50 Further developments in dynamic control of earthquake engineering facilities (FUDIDCOEFF)
Laboratório Nacional de Engenharia Civil (PT); University of Bristol (GB).

51 Active Control in Civil Engineering (ACE)
Bouygues (FR); Johs. Holt AS (NO); Magnetostrictive Technology Systems Ltd. (GB); Mannesmann Rexroth GmbH (DE); Ministry of Defence (GB); Technische Universität Dresden (DE); Université Libre de Bruxelles (BE); VSL France SA (FR).

52 Towards European Integration in Seismic Design and Upgrading of Building Structures (EUROQUAKE)
Ismes SpA (IT); University "Kiril and Metodij" (YU); University of Bristol (GB); University of Bucharest for Agricultural and Veterinary Sciences (RO); University of Ljubljana (SI); Ustav Stavebnictva a Architektury - Slovak Academy of Sciences (SK).

53 Human Factors in Aircraft Dispatch and Maintenance Safety (ADAMS)
British Airway PLC (GB); Ministry of Defence (GB); Nationaal Lucht- en Ruimtevaart Laboratorium (NL); Sabena S.A. (BE); Scandinavian Airlines System (SE); University of Dublin - Trinity College (IE).

54 Development of a Method for Air Transport Safety Improvement Through Quantitative Risk Evaluation (DESIRE)
Airbus Industrie (FR); Airclaims Ltd. (GB); Nationaal Lucht- en Ruimtevaart Laboratorium (NL); Sextant Avionique SA (FR); SG Services Limited (GB).

55 Human Factors Safety Training On The Internet (SAFETYNET)
AVITRACO A/S (DK); Danish CAA-Academy (DK); Danish Maritime Institute (DK); DEDALE (FR); Risø National Laboratory (DK); SAS Flight Academy (SE).

56 Integrated Approach for Fatigue Design of Low Weight Vehicle Suspension Components (FADIN)
Centro Ricerche Fiat SCpA (IT); GKN Sankey - Engineering Products (GB); Mechanical Dynamics GmbH (DE); Rover Group Ltd. (GB); Tecmath GmbH (DE); Teksid SpA (IT); University of Dublin - Trinity College (IE); Volkswagen AG (DE).

57 Remotly operated tanker inspection system (ROTIS)
Avin Oil Trader Maritime Company (GR); CS & Associates Ltd. (GR); ENEA - Ente per le Nuove Tecnologie, l'Energia e l'Ambiente (IT); General Robotics Ltd. (GB); Helsinki University of Technology (FI); Lloyd's Register of Shipping and Industrial Services S.A. (GR); TECNOMARE (IT).

58 Arctic Demonstration and Exploratory Voyage (ARCDEV)
Central Marine Research and Design Institute Ltd (RU); Earth Observation Sciences Ltd (GB); Fachhochschule Hamburg (DE); Hamburgische Schiffbau-Versuchsanstalt GmbH (DE); Helsinki University of Technology (FI); Kvaerner Masa-Yards Inc. (FI); Lloyd'S Register of Shipping (GB); MTW Schiffswerft GmbH (DE); Nansen Environmental and Remote Sensing Center (NO); Neste Oy (FI); Remtec Systems Ltd (FI); Shell Vankor Development B.V. (NL); Tecnomare S.P.A. - Società per lo Sviluppo delle Technologie Marine (IT).

59 Detection and assessment of seismic damage in reinforced concrete, transportation, primary tunnel linings (TUNNELLING)
Computer Technology Institute (GR); M3D Materials, Development, Design and Devices (FR); TECNIC Consulting Engineers SpA (IT).

60 Characterisation of processes which govern quenching of molten corium in water, including steam explosion (MFCI)
AEA Technology Plc. (GB); Ansaldo SpA (IT); Commissariat à l'Energie Atomique (FR); ENEA - Ente per le Nuove Tecnologie, l'Energia e l'Ambiente (IT); Forschungszentrum Karlsruhe GmbH (DE); Kungliga Tekniska Hogskolan (SE); Siemens AG (DE); Société Framatome (FR).

61 Corium spreading and coolability (CSC)
Commissariat à l'Energie Atomique (FR); Electricité de France (FR); ENEA - Ente per le Nuove Tecnologie, l'Energia e l'Ambiente (IT); Forschungszentrum Karlsruhe GmbH (DE); Kungliga Tekniska Hogskolan (SE); Siemens AG (DE); Société Framatome (FR); Universität Stuttgart (DE); Université de Provence, Aix-MarseilleI (FR).

62 Containment behavior in the event of core melt with large gaseous and aerosol releases (CONGA)
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (ES); ENEL SpA (IT); Paul Scherrer Institut (CH); Siemens AG (DE).

63 Iodine chemistry
AEA Technology Plc. (GB); Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (ES); Commissariat à l'Energie Atomique (FR); IVO International Ltd. (FI); NNC Ltd. (GB); Siemens AG (DE).

64 JSRI - Light Water Reactor Safety (JSRI)
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (ES); Commissariat à l'Energie Atomique (FR); ECN (BE); ENEA - Ente per le Nuove Tecnologie, l'Energia e l'Ambiente (IT); Federal Chancellery (AT); Health and Safety Executive (GB); National Centre for Scientific Research "Demokritos" (GR); Risø National Laboratory (DK); SCK/ECN (BE); SKI (SE).

65 Fission product release and speciation
AEA Technology Plc. (GB); Commissariat à l'Energie Atomique (FR); ENEA - Ente per le Nuove Tecnologie, l'Energia e l'Ambiente (IT); Ruhr-Universität Bochum (DE); Universität Stuttgart (DE).

66 Benchmarking Release, Circuit and Containment Codes against Phebus FP (PHEBEN)
AEA Technology Plc. (GB); Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (ES); Commissariat à l'Energie Atomique (FR); ENEA - Ente per le Nuove Tecnologie, l'Energia e l'Ambiente (IT); Forschungszentrum Karlsruhe GmbH (DE); Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH (DE); Österreichisches Forschungszentrum Seibersdorf GmbH (AT); Universidad Politécnica de Madrid (ES); Università degli Studi di Pisa (IT); Universität Stuttgart (DE).

67 Assessment of models for fission product revaporization (Revap - Assess)
AEA Technology Plc. (GB); Commissariat à l'Energie Atomique (FR); Sandia National Laboratory (US); Technical Research Centre of Finland (FI); Universität Stuttgart (DE).

68 Archive for source term information and system models (ASTERISM)
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69 Validation strategies for severe accident codes (VASA)
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70 Experimental and computational modelling of corium formation and behaviour during a severe accident in a light water reactor (COBE)
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71 Investigation of oxidation phenomena in severe accidents (OPSA)
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72 Multidimensional simulation of hydrogen distribution and turbulent combustion in severe accidents (Hydrogen Risk)
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73 Benchmark Exercise on Expert Judgment Techniques in PSA Level 2 (BE-EJT)
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74 A dataset for level 2 probabilistic safety analysis studies (PSAL2)
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75 Integrated sequence analysis and new approaches to human reliability (ISANEW)
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76 Behaviour of the reactor pressure vessel under mechanical and thermal loadings caused by core melt-down and steam explosion accidents (RPVSA)
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77 Reactor vessel integrity in severe accidents (REVISA)
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78 Validation Of Laser Welding Technology For Heavy Section Components (LASEROBOT)
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79 Semi-autonomous monitoring and robotics technology (SMART II)
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80 Quality control of nuclear waste packages with a Compton suppression and Ge-telescope detection system
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81 Round robin test for non destructive assays of 220 litres radioactive waste packages
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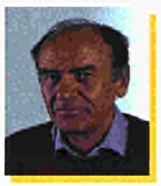

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Summary

The 1998 Annual Report of the Joint Research Centre's Institute for Systems, Informatics and Safety (ISIS) presents the main results from its research programme and from the scientific/technical support within the European Commission. The report also highlights the 81 collaborative projects (Shared-Cost Actions) awarded within the Fourth Framework Programme.

The themes covered are:

- Information society
- Fight against fraud
- Sustainable development
- Risk analysis and emergency management for natural and man-made hazards
- Safety of civil engineering and cultural heritage structures
- Transport safety
- Nuclear reactor safety
- Nuclear safeguards
- Conservation of cultural heritage

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